Atlantic Outer Continental Shelf

# Drilling and Production Discharges and Oil Spills in the Marine Environment

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## PREFACE

In compliance with the procedures and goals established by the National Environmental Policy Act, the U.S. Department of the Interior, through the Minerals Management Service, prepares Environmental Impact Statements (EIS's) for proposed Outer Continental Shelf (OCS) Oil and Gas Lease Sales. This Environmental Support Document is a compilation of in-house analyses and studies conducted as part of the EIS preparation process. Portions of previously published EIS's are included as well. The purpose of this document is to ensure that environmental information used in the preparation of EIS's is widely available to public officials, coordinating agencies, affected States, and the public.

This document is not intended to be used as a local planning document by potentially affected communities. The OCS oil and gas operations described in this document are used as a basis for describing characteristic activities in the Atlantic OCS Planning Areas. Local control of events may be exercised through planning, zoning, land ownership, and applicable State and local laws and regulations. Any use of trade names is used for descriptive purposes only and does not constitute endorsement of these products by the Minerals Management Service.

This Environmental Support Document is one of a series concerning the Atlantic OCS marine environment. Another publication in this series, *Description of the Mid-Atlantic Environment*, also is available from the Atlantic OCS Region. Reasonable quantities of these documents are available, free of charge, from:

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# SUMMARY

The potential effects of Outer Continental Shelf (OCS) oil and gas operations on the marine environment have been the subject of much research and public debate. The potential adverse impacts from drilling and production discharges and oil spills on marine ecosytems are important environmental issues.

Oil industry operations on the OCS typically result in discharge of drilling muds and cuttings as well as small amounts of oil and wastewater. All offshore discharges are regulated by the Federal Government according to the administrative framework established by the Clean Water Act of 1977, and the Outer Continental Shelf Lands Act, as amended (OCSLA). The Clean Water Act prohibits the discharge, into navigable waters of the OCS, of oil or hazardous substances which may affect natural resources except under limited circumstances. Principal authority to regulate discharges to the water from OCS oil and gas operations lies with the Environmental Protection Agency (EPA) through the National Pollutant Discharge Elimination System (NPDES) established by the Clean Water Act. Pursuant to the Act, EPA has established effluent limitations applicable to OCS exploratory drillships, semisubmersible vessels, and jackup rigs used in exploration activities based on use of the "best practicable control technology currently available." In accordance with the NPDES program, EPA issues permits for the discharge of both drilling material and wastewater from exploratory vessels and production platforms on the OCS. In addition, MMS controls discharges through lease stipulations and OCS regulations under authority of the OCSLA.

Drilling muds are required in oil and gas exploration to remove cuttings (rock particles or fragments from the formation drilled) from beneath the bit, to cool and lubricate the drill bit and drill pipe, to control formation pressure, and to seal the well. These muds are complex mixtures composed of bulk constituents and special purpose additives. The primary bulk components are water, barite, clay minerals, chrome lignosulfate, lignite, and sodium hydroxide. Speciality additives such as bactericides and diesel fuel may be added to control mud properties. The EPA and the MMS restrict the discharge of muds containing diesel fuel.

Drill muds are recirculated and, in the case of multiple well completions, reused. However, the muds must be disposed of eventually due to contamination with suspended material or loss of desired mud properties. Throughout drilling operations, drill muds are discharged intermittently into the water column to maintain desired mud properties. Except in the case of multiple well completions, there is a bulk discharge at the completion of a well. Only those muds which EPA finds environmentally acceptable, based on bioassay results, can be discharged. Eight standard muds with low toxicities have received EPA approval for operations in the Atlantic OCS. Over 95 percent of the muds discharged on the OCS are clay-chrome lignosulfate muds.

Cuttings removed from the drilling mud are usually discharged continuously into the water column by either overboard discharge or shunting through a pipe to some depth. Typically, for an exploratory well in the Atlantic OCS, 5,000 to 30,000 bbl of drilling mud and 3,000 to 6,000 bbl of wet solids (mostly cuttings) are discharged over the lifetime of the well. For a development well, the quantity is generally less.

In addition to oil and gas production, formation water also is recovered during petroleum production. The method of recovery and the nature of the formation

determine the amount of produced water. Typically, as oil and gas production declines, wells produce increasing amounts of formation water. These waters may contain entrained hydrocarbons, high trace metal concentrations, and low dissolved oxygen concentrations which have a potential for environmental effects. However, numerous studies show these waters undergo rapid dilution upon release. A study on the Buccaneer Oil Field in the Gulf of Mexico demonstrated low toxicity of produced water in the water column surrounding an outfall. Under the NPDES permit program, EPA requires treatment of produced waters for oil prior to discharge. Produced waters are often reinjected to help maintain reservoir pressure or to avoid significant degradation of local ambient water quality.

Deck drainage, and domestic and sanitary wastes also are discharged from offshore oil and gas facilities. Deck drainage includes all effluents resulting from platform and deck washings, as well as runoff from curbs, gutters, and work areas. Because these effluents may initially contain oil and grease, all contaminated deck drainage is treated for removal of solids and oil before it is discharged.

Oil spills are another major concern of exploration, development, and production of offshore hydrocarbon resources. Historically, major OCS oil spills ($\geq$1,000 bbl) have been the result of pipeline accidents, platform accidents such as well blowouts or fires, and tanker and barge accidents. Although blowouts can occur during well drilling, completion, or production operations, most oil spillage results from producing rather than exploratory wells. Only 0.64 percent of all exploratory wells drilled on the U.S. OCS have resulted in blowouts, and none of those blowouts have resulted in spillage of oil. According to Gulf of Mexico data, most oil spills from all types of OCS activities are small (less than 50 bbl).

In addition to oil spill accidents, low-level petroleum inputs to the marine environment occur during operational discharges from exploratory rigs, platforms, tankers, and support vessels. Stringent requirements directed at preventing marine pollution from both accidental and operational discharges by tank vessels were established by the 1978 Port and Tanker Safety Act and the 1980 Act to Prevent Pollution from Ships. The implementing regulations for these two acts are under the authority of the Coast Guard.

According to the NRC, only about 2 percent of the petroleum discharged into the marine environment is the result of offshore production. Additionally, NOAA estimates that, for most years, the total input of oil into the Atlantic OCS marine environment by operational discharges unrelated to OCS oil and gas activities far exceeds that from accidental spills.

There are different levels of oil spill impacts depending on the physical and chemical properties of the oil and the progressive series of changes in these properties as the oil weathers. The weathering of a slick begins immediately after it has been spilled and continues at rates which vary depending on the type of oil and the ambient oceanographic and meteorologic conditions. Major processes which contribute to the weathering of oil are evaporation, dispersion, dissolution, emulsification, biodegradation, photo-oxidation, and sedimentation. The more toxic and lighter components of oil weather most rapidly. Eventually, only a tar-like residue remains which breaks up into tar lumps or tar balls.

Although much effort is dedicated to spill prevention by both industry and the Federal Government, the possibility that an oil spill could occur must be anticipated. In the event of accidental oil discharge during any stage of offshore operations, OCS regulations, implemented by MMS and the NCP, provide assurance of a rapid and coordinated Federal response. Specifically, the NCP provides guidelines for an integrated response by Departments and Agencies of the Federal Government as well as outlining the division of responsibilities among the Federal, State, and local governments. In addition, Title III of the OCSLA establishes an Offshore Pollution Compensation Fund in the U.S. Treasury. This is a spill liability fund which provides compensation for economic loss resulting from oil pollution. Money for the fund is generated by fees levied on OCS-produced oil.

Federal responsibility for oil spill cleanup on the OCS is assumed by the Coast Guard. A Memorandum of Understanding (MOU) between the Departments of the Interior and Transportation outlines the respective responsibilities of the MMS and Coast Guard regarding cleanup efforts. The MMS is responsible for the coordination and direction of abatement measures while the Coast Guard has the authority to take control of the cleanup operation if the efforts by the operator are inadequate.

The Coast Guard provides On-Scene Coordinators (OSC's) who direct the Federal response to oil discharges. Although the owner of the tanker or facility is responsible for cleanup, it is the responsibility of the OSC to determine if the proper countermeasures are being taken. If it is determined that an adequate response is not being made, cleanup activities are undertaken by the Federal Government.

Additional guidelines addressing oil spill control are contained in OCS regulations. For both exploration and production operations, lessees are required to submit an Oil Spill Contingency Plan (OSCP) to MMS for approval. The OSCP assures that full response capability can be committed during an oil spill, including specification of appropriate equipment and materials, their availability, and the time needed for deployment. The MMS has the authority to specify the location, type, and amount of cleanup equipment maintained during offshore operations.

The effectiveness of oil spill cleanup depends largely on the circumstances characterizing the spill, such as the rate, volume, and type of oil spilled, the weather and sea conditions, and the location. The response measures after a spill in the open ocean can be broadly classified as either natural cleansing, mechanical recovery (booms, skimmers, or sorbents), or chemical dispersal.

Booms and skimmers are used primarily for large spills while sorbents are useful in small spills. Booms are mechanical barriers which extend above and below the water surface. They are used to contain oil for recovery, divert and concentrate oil to facilitate recovery, and protect commercially valuable or environmentally sensitive areas. Containment booming is most effective in waves up to 1.5 m (5 ft).

Skimmers are mechanical devices designed to remove oil from the water surface for disposal. Most skimmers are classified as weir skimmers (rely on gravity drain-off of oil), suction skimmers (remove oil by means of a vacuum pump), centrifugal skimmers (operate by creating a whirlpool that draws the oil into a collection area), or oleophilic skimmers (collects oil on a sorbent surface). Skimmers have a recovery rate of up to 700 $m^3$/h and a maximum recovery efficiency of approximately 90 percent.

Sorbents are materials which will recover oil through either absorption or adsorption. There are three basic categories of sorbents: (1) natural organic materials such as straw, peat, and sawdust; (2) synthetic organic materials such as polyurethane, polypropylene, and rubber; and (3) mineral-based sorbents such as perlite, vermiculite, and glass wool. Of these, the synthetic sorbents have the highest recovery efficiency and, in addition, are easy to apply and recover.

Although oil will disperse naturally as it spreads and weathers, chemical dispersants accelerate the process by reducing the surface tension between oil and water. Dispersion of the oil enhances weathering processes such as oxidation and biodegradation. Use of dispersants may be considered in the open ocean when conditions preclude the use of booms and skimmers, or when an oil slick is threatening areas of biological, cultural, historical, or recreational importance. Use of dispersants is regulated under the National Oil and Hazardous Substances Pollution Contingency Plan as well as regional contingency plans because of potential toxic effects.

# 1 DRILLING AND PRODUCTION DISCHARGES IN THE ATLANTIC OCS MARINE ENVIRONMENT

The Federal Water Pollution Control Act (FWPCA; 33 U.S.C. 1251 *et. seq.*), as amended by the Clean Water Act (CWA or the Act) of 1977, establishes a policy to provide for water pollution control activities to restore and maintain the chemical, physical, and biological integrity of the Nation's waters. Under the Act, the Environmental Protection Agency (EPA) regulates offshore oil and gas drilling- and production-related discharges on the Outer Continental Shelf (OCS) through the National Pollutant Discharge Elimination System (NPDES) established under Section 402 of the Act. This section establishes requirements for Federal permits and licenses to conduct any activity which may result in a discharge into navigable waters. The NPDES permits apply to all sources of wastewater discharges from exploratory vessels and production platforms operating on the OCS.

Section 311 of the Act prohibits any discharge of oil or hazardous substances into the navigable waters of the United States which may affect natural resources, except under limited circumstances. It also establishes civil penalty liability and enforcement procedures to be administered by the Coast Guard. According to the Act, point-source discharges must achieve effluent limitations (40 CFR 435) through the use of BPT, "best practicable control technology currently available."

Under the authority of the OCS Lands Act (OSCLA) Amendments of 1978, the U.S. Department of the Interior, Minerals Management Service (MMS) also regulates offshore oil and gas industry discharges through lease stipulations and OCS regulations (30 CFR 250).

Table 1-1 lists potential drilling-rig discharges into the offshore waters of the Atlantic OCS. It should be noted that the fates and effects of drilling discharges, especially discharges of muds, cuttings, and formation waters, have been the subject of considerable controversy concerning their relative toxicity to marine life. However, the National Research Council (NRC, 1983) found the ecological effects of individual discharges are quite limited in extent and are mainly confined to the benthic environment. The NRC suggests the environmental risks of exploratory drilling discharges to most OCS communities are small.

## 1.1 Drilling Muds and Cuttings

Drilling muds perform several functions integral to the drilling process. They transport cuttings to the surface; balance subsurface and formation pressure; prevent blowout; and cool, lubricate, and partly support the drill bit and drill pipe. During drilling, the mud is tested continually and adjusted to counteract changes in downhole conditions. Mud composition is changed continually as the well is drilled by the use of additives and by the naturally-occurring rock formations being drilled, so that no two drilling muds are identical (Neff, 1987a).

Drill cuttings are rock particles or fragments which are displaced as the drill moves through the various geological formations. During drilling operations, the mud is circulated down the well through the drill pipe where it picks up cuttings and returns to the surface. Next, the mud is passed through solids control equipment to remove the cuttings. This equipment consists of shale-shaker screens to remove coarse particles, and hydrocyclones to remove most of the sand and silt fractions from the mud. Once separated, the cuttings are discharged into the ocean and the mud is

Table 1-1. Typical drilling discharges

| Discharge | Average Flow Rate | | | |
|---|---|---|---|---|
| | Minimum | | Maximum | |
| | gpd | $m^3/d$ | gpd | $m^3/d$ |
| Drilling Mud System (Active and Reserve Drains) | 1,800 | 6.8 | 11,300 | 42.8 |
| Drill Cuttings and Washwater | 4,000 | 15.1 | 12,000 | 45.4 |
| Contaminated Deck Drainage (Work Area Drainage) | 800 | 3.2 | 14,000 | 53.0 |
| Sanitary Waste Discharge (Salt Water Used) | 1,500 | 5.7 | 5,000 | 18.9 |
| Kitchen & Shower Discharge (Grey Water) | 1,500 | 5.7 | 8,000 | 30.3 |
| Water Distillation Discharge (Salt Water Brine) | 5,000 | 18.9 | 36,000 | 136.3 |
| Clean Deck Drainage (Rain-water and Washwater) | 2,800 | 10.6 | 13,200 | 50.0 |
| BOP (Blowout Prevention System) Fluid | 10 | 0.1 | 500 | 1.9 |
| Boiler Blowdowns | - | - | 200 | 0.1 |
| Cooling Water (Power Generation System) | 400,000 | 1515 | 5,200,000 | 19,690 |
| Ballast Water (with no additives) | 3,000 | 11.4 | 26,000 | 98.4 |
| Cementing Unit & Washdown Drains | 20 | 0.1 | 500 | 1.9 |

Source: Modified from EPA, 1981.

returned to tanks for recirculation. Drill cuttings are discharged continuously during drilling operations. The bulk of the discharged cuttings occurs from the 0 to 1,520 m (0 to 4,985 ft) depth zone (usually the first third of a program). As well depth increases, there is a decrease in the volume of cuttings per foot, a reflection of the decrease in drill bit size. For this reason, there are very small amounts of drill cuttings discharged during the last third of the well drilling operation (Petrazzuolo, 1981). Drilling muds, however, can be recirculated and, in the case of multiple production well drilling, reused. Eventually, however, the muds must be discharged into the ocean when laden with suspended material or when they lose important physical or chemical properties necessary for drilling. The largest daily discharges, thus, are likely to occur at the beginning and end of the drilling program.

Given cost and operational considerations, as well as minimal environmental impacts, ocean disposal of drilling muds and cuttings by discharge at the ocean surface or shunting through a pipe at some depth is more favorable than barging the discharges ashore. The quantities and properties of the discharged muds and cuttings depend on the well depth, hole size, geologic formations encountered, mud dispersability, and solids control capacity.

For an exploratory well, such as those previously drilled in the Atlantic, 5,000 to 30,000 bbl of drilling muds and 3,000 to 6,000 bbl of wet solids (mostly cuttings) are discharged into the water column over the lifetime of the well (Ayers, 1983). The quantity of discharge from a development well is likely to be less since it is normally shallower, smaller in diameter, and requires less time to drill than an exploratory well. Specifications for the discharge of drilling materials (e.g., depth, rate) are designated by the EPA in accordance with the NPDES permit program and by the MMS under OCS regulations (30 CFR 250).

Drilling muds consist of a wide variety of naturally occurring minerals (e.g., bentonite, barite), simple chemicals (e.g., sodium hydroxide, sodium bicarbonate, potassium chloride), complex organic compounds (e.g., lignosulfonates, formaldehydes), and other materials (Houghton et al., 1981). Basically, muds used on the Atlantic OCS are a water-based clay (usually bentonite) suspension which contains barite for density control as well as lower concentrations of chrome lignosulfonate, sodium hydroxide, lignite, and other chemical additives to control viscosity, fluid loss, corrosion, and other mud properties (EPA, 1981). Early in drilling when structural or conductor casings are being run and cemented, the drilling mud usually is mostly seawater or a seawater-bentonite fluid. At the end of the drilling program, the fluid is generally a high-density ferrochrome-lignosulfonate freshwater mud (Petrazzuolo, 1981).

On the OCS, over 95 percent of the muds discharged are clay-chrome lignosulfonate-type muds. These muds contain water, barite, bentonite clay, chrome lignosulfonate, lignite, formation solids, cellulose polymer, caustic soda, and inorganic salts. These ingredients account for more than 99 percent of the mass of mud discharged. Other ingredients (e.g., defoamers, oxygen scavengers) are added in low concentrations only during special situations (Ayers, 1983).

Only those muds designated by the EPA to be environmentally acceptable, as determined by bioassay test results, can be discharged on the OCS. Based on the low toxicity demonstrated through bioassay analyses, conducted as part of the offshore operators' mid-Atlantic discharge permit conditions, eight standard (generic) muds have received EPA approval for operations in the Atlantic. The permits specify the major components and allowable concentration ranges rather than specific concentration requirements. The major components used in the formulation of each of the standard muds are given in Table 1.1-1. It should be noted that no two mixtures of the same generic mud will have exactly the same concentration of materials or associated trace metals since these vary with each drilling situation and the purity of materials such as barite, bentonite, and lignosulfonate.

Additives needed for special drilling situations are not named in the generic mud formulations. If need for such an additive arises, an operator must submit its chemical composition, usage rates, and toxicity data to the EPA prior to its use. The EPA

Table 1.1-1. Standard drilling muds

| Type of Fluid | Components | Permissible Content (lb/bbl) |
|---|---|---|
| (1) Potassium/ polymer | Barite | 0-450 |
| | Caustic soda | 0.5-3 |
| | Cellulose polymer | 0.25-5 |
| | Drilled solids | 20-100 |
| | Potassium chloride | 5-50 |
| | Seawater or freshwater | As needed |
| | Starch | 2-12 |
| | XC polymer | 0.25-2 |
| (2) Seawater/ lignosulfonate | Attapulgite or bentonite | 10-50 |
| | Barite | 25-450 |
| | Caustic soda | 1-5 |
| | Cellulose polymer | 0.25-5 |
| | Drilled solids | 20-100 |
| | Lignite | 1-10 |
| | Lignosulfonate | 2-15 |
| | Seawater | As needed |
| | Soda ash/sodium bicarbonate | 0-2 |
| (3) Lime | Barite | 25-180 |
| | Bentonite | 10-50 |
| | Caustic soda | 1-5 |
| | Drilled solids | 20-100 |
| | Freshwater or seawater | As needed |
| | Lignite | 0-10 |
| | Lignosulfonate | 2-15 |
| | Lime | 2-20 |
| | Soda ash/sodium bicarbonate | 0-2 |
| (4) Nondispersed | Acrylic polymer | 0.5-2 |
| | Barite | 25-180 |
| | Bentonite | 5-15 |
| | Drilled solids | 20-70 |
| | Freshwater or seawater | As needed |
| (5) Spud (slugged intermittently with seawater) | Attapulgite or bentonite | 10-50 |
| | Barite | 0-50 |
| | Caustic soda | 0-2 |
| | Lime | 0.5-1 |
| | Seawater | As needed |
| | Soda ash/sodium bicarbonate | 0-2 |

Table 1.1-1. Standard drilling muds - Continued

| Type of Fluid | Components | Permissible Content (lb/bbl) |
|---|---|---|
| (6) Seawater/ freshwater gel | Attapulgite or bentonite | 10-50 |
| | Barite | 0-50 |
| | Caustic soda | 0.5-3 |
| | Cellulose polymer | 0-2 |
| | Drilled solids | 20-100 |
| | Lime | 0-2 |
| | Seawater or freshwater | As needed |
| | Soda ash/sodium bicarbonate | 0-2 |
| (7) Lightly treated lignosulfonate freshwater/ seawater | Barite | 0-180 |
| | Bentonite | 10-50 |
| | Caustic soda | 1-3 |
| | Cellulose polymer | 0-2 |
| | Drilled solids | 20-100 |
| | Lignite | 0-4 |
| | Lignosulfonate | 2-6 |
| | Lime | 0-2 |
| | Seawater-to-freshwater ratio | approx. 1:1 |
| (8) Lignosulfonate freshwater | Barite | 0-450 |
| | Bentonite | 10-50 |
| | Caustic soda | 2-5 |
| | Cellulose polymer | 0-2 |
| | Drilled solids | 20-100 |
| | Freshwater or seawater | As needed |
| | Lignite | 2-10 |
| | Lignosulfonate | 4-15 |
| | Lime | 0-2 |
| | Soda ash/sodium bicarbonate | 0-2 |

Source: National Research Council, 1983.

approves or disapproves the discharge of muds containing specialty additives on a case-by-case basis under Section 301(c) of the CWA. However, continuing need for a particular specialty additive requires the submission of bioassay test data for approval to discharge a mud containing that additive (Ayers et al., 1983; Neff, 1987). EPA is currently studying allowable effluent limitations but final BAT (best available technology economically achievable) and BCT (best conventional pollutant control technology) effluent limitations and NSPS (New Source Performance Standards) for offshore drilling wastestreams are not expected to be promulgated until 1990 (*Federal Register*, 53(165):32584-32589).

Table 1.1-2 contains a list of typical mud additives. At any given well, depth, and time, a dozen or more additives may be used to control downhole conditions (API, 1978).

Table 1.1-2. Typical drilling mud components

| Trade Name | Constituents | Usage |
|---|---|---|
| Aluminum/Stearate | Organometallic compound | S |
| Aquagel | Sodium montmorillonite | N |
| Barite | Barium sulfate | N |
| Carbonox | Lignite humic acid powder | N |
| Caustic soda | Sodium hydroxide | N |
| Cellex | Sodium carboxymethylcellulose | S |
| Drispac | Polyanionic cellulosic polymer powder | N |
| Impermex | Starch | S |
| Lime | Calcium hydroxide | N |
| Micatex | Mica flakes | S |
| Q-Broxin | Ferrochrome lignosulfonate | N |
| SAPP | Sodium acid pyrophosphate | S |
| Soda Ash | Sodium carbonate | N |
| Sodium Bicarbonate | Sodium bicarbonate | S |
| Torq-trim | Biodegradable, nontoxic lubricant | N |
| Walnut | Nut hulls | S |
| X-C Polymer | Biopolysaccharide gum | S |
| Ziogel | Attapulgite clay | S |

N - Normal Mud Constituent.
S - Special Mud Constituent (for specific well problems).
Source: EPA, 1981.

Bactericides most commonly are included in drilling muds containing starch or polymers which are rapidly degraded by heat, agitation, or microorganisms (NRC, 1983). All bactericides used in drilling muds are regulated by the EPA under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), and by EPA and MMS discharge stipulations. MMS has banned chlorinated phenols (e.g., Dowicide G-S and Surflo B-33) from use on the OCS due to their toxicity. Paraformaldehyde (e.g., Aldacide) is now the most common bactericide used in drilling muds. It depolymerizes to formaldehyde, the active ingredient, upon contact with water and exhibits a relatively low toxicity for marine animals (NRC, 1983).

Drilling additives that are prohibited from being discharged on the Atlantic OCS include oil-based drilling muds, halogenated phenol compounds, asbestos, sodium chromate, sodium dichromate, and trisodium nitrilo triacetic acid. The EPA has prohibited the discharge of these highly toxic materials because suitable substitutes are available (EPA, 1981). If diesel fuel is needed to deal with a special drilling problem, such as a stuck casing or pipe, it must be separated from the muds prior to discharge. Although a minute quantity will remain adhered to any discharged cuttings, these trace amounts are allowable discharges under the NPDES permit.

Because drilling muds are extremely heterogeneous and the purity of major ingredients like barite, bentonite, and lignosulfonate varies greatly, metal concentrations in drilling muds are also variable (Neff, 1981). The heavy metals used in drilling muds include barium, chromium, cadmium, copper, iron, mercury, lead, and zinc. Arsenic, nickel, vanadium, and manganese also may be present. Some of these metals are added intentionally to drilling muds as metal salts or organometallic compounds (Neff, 1981). Others are trace contaminants of major mud ingredients, such as barite (e.g., cadmium and mercury) (Neff, 1981), and are present in very low concentrations at or below background levels in the environment or even beyond the limits of measurement. Some trace metals present in used muds also originate from formation solids.

The composition of drilling mud also can change in response to downhole conditions. At temperatures and pressures encountered in geologic formations, chemical reactions may alter the composition or structure of the drilling mud. It is this modified mud that is discharged to the marine environment (NRC, 1983).

## 1.2 Fate and Effects of Drilling Discharges

The fate and effects of drilling discharges have been the subject of extensive research and controversy in recent years with considerable concern expressed by regulatory agencies, the fishing industry, and citizens regarding the ecological effects on marine ecosystems and resources. However, the NRC conducted a comprehensive study critically reviewing the technical basis for decisionmaking concerning the discharge of drilling muds and cuttings into the marine environment. The NRC concluded that these discharges pose minimal risk to the marine environment in all but limited situations because physical conditions at open-ocean drilling sites generally dissipate the discharges to levels that are environmentally innocuous. Specifically, muds discharged on the Federal OCS "have low acute and chronic toxicities to marine organisms" and "effects of individual discharges are quite limited in extent and are confined mainly to the benthic environment . . . suggest[ing] that the environmental risks of exploratory drilling to most OCS communities are quite small" (NRC, 1983). Furthermore, although "Discharges from oil and gas field development drilling introduce greater quantities of materials into the marine environment over longer periods of time, results of field studies suggest that the accumulation of materials from these longer term inputs is less than additive and therefore the effects of exploratory drilling provide a reasonable model for projecting the effects of development drilling." At the same time, the NRC called for implementation of measures to prevent discharge practices that might bury reef corals and other particularly sensitive sea floor environments that are not exposed to natural sediment changes and recommended that diesel fuel and other toxic drilling additives be strictly monitored or controlled.

Nevertheless, concern remains and has centered on the solid particles (cuttings), heavy metals, trace organic materials (e.g., lignite and lignosulfonate), and specialty additives in drilling discharges. Bioassay toxicity data have indicated that most drilling mud components are relatively non-toxic, but some constituents, particularly heavy metals and bactericides, can be toxic and persistent. Other components such as calcium, magnesium, aluminum, sodium, potassium, and chlorine are the normal components of ordinary clay and have shown a relatively low toxicity to marine life (NRC, 1983; Neff, 1981).

In order to determine the fate and effects of discharged drilling materials in the marine environment, rig-monitoring studies were conducted at drilling locations off California, Alaska, the Gulf of Mexico, and the north and mid-Atlantic (see Ayers et al., 1980a and b; Battelle and WHOI, 1983, 1984, and 1985; Bothner et al., 1982, 1983, and 1985; Ecomar, Inc., 1978; EG&G, 1982; Houghton et al., 1981; Maciolek et al., 1987; Meek and Ray, 1980; Payne et al., 1983; Ray and Meek, 1980; Trefry et al., 1981; Trocine and Trefry, 1982; Zingula, 1975; Zingula and Larson, 1977). These studies monitored the dilution, dispersion, transport, and impacts of drilling muds and cuttings on water quality, bottom sediments, and biota. The studies demonstrated that effects on ambient water quality and hydrography are minor, localized, and temporary because of the immediate settling of the bulk of the solids and the rapid dispersion of the remaining particles. Water temperature and pH may become slightly elevated, while dissolved oxygen and salinity may decrease, but measurements of these parameters at 40 m (131 ft) from the point of discharge have shown them to be unchanged from background levels. Beyond the immediate area of discharge, the only parameters affected by drilling material discharges are suspended solids levels and light transmittance (Ayers et al., 1980a and b; EG&G, 1982; Ray and Meek, 1980).

Studies in the mid-Atlantic by Maciolek et al. (1987) have shown effects on water quality from drilling discharges to be low and temporary in nature. Despite the seemingly large amounts of drilling muds and cuttings discharged during drilling operations, the effect of these discharges on water quality is attenuated by (1) requirements to meet EPA criteria; (2) rapid dilution upon discharge; and (3) the fact that not all wells could be drilled at the same time nor in the same area (NRC, 1983).

The distance from a drilling rig to the point where drilling muds are dispersed and the concentration of mud in bottom sediments depends on the type and quantity of mud discharged, the hydrographic conditions at the time of discharge, and the height above bottom at which the discharge was made (Neff, 1987a). The bulk of discharged drilling materials will settle rapidly with the heaviest materials (e.g., cuttings) accumulating closest to the discharge point and any lighter mud components, capable of being suspended and transported in the water column, settling somewhat farther away. The lighter particulate and soluble components of the discharge would be dispersed and diluted to ambient levels within a short distance from the discharge point. In shallow (<60 m [196 ft]) areas, some discharged materials may be resuspended and transported elsewhere as a result of storm-related events. The mid-

Atlantic Block 684 studies (EG&G, 1982) in a water depth of 43 m (140 ft) showed that drilling discharges in deeper waters are not dispersed by the low-energy bottom environment. On the slope and rise, discrete bottom accumulations of drilling discharges are unlikely because of the increased settling distance afforded by the greater depth. In deep water, part of the discharge (except for the heaviest cuttings), may descend until reaching a point of neutral buoyancy, rather than settling directly to the bottom (NRC, 1983). As a result, this material can remain temporarily suspended in a secondary plume and, thereby, increase its ultimate distribution over the bottom.

Once drilling muds and cuttings settle to the bottom or disperse in the water column to background levels, they no longer contribute to water quality degradation unless resuspended in the water column. The bulk of discharged drilling materials (over 90 percent) settles rapidly (in less than 1 hour) around the point of discharge. Concentrations of solids in the water column may approach laboratory bioassay 96-hour $LC_{50}$ values of 10,000 to >100,000 ppm when a discharge is actually occurring and is measured in the immediate vicinity of the discharge pipe. Depending on the rate of discharge, total volume, and local hydrographic conditions, the suspended solids concentrations usually are reduced to 0.01 percent or less of the original value (less than 1 to 10 ppm) within 100 m (328 ft) of the discharge and, with continued settling and dispersion, normally approach background levels within 1,000 m (3,280 ft) downcurrent. Such concentrations are far below the 100 to 1,000 ppm range that most investigators have noted as having sublethal effects on marine biota. The actual transport time required for suspended solids to reach background levels is an increasing function of the rate of discharge (Ayers, 1980 and 1981; Ayers et al., 1980a; NRC, 1983).

A rig-monitoring study conducted on mid-Atlantic Block 684, located on the shelf southwest of Hudson Canyon, in approximately 122 m (400 ft) of water, found the majority of discharged material was carried away from the rig by the prevailing currents. Suspended solids concentrations approached background levels within 350 to 600 m (1,148 to 1,968 ft) of the discharge source (Ayers et al., 1980b; EG&G, 1982). In the Gulf of Mexico (Ayers et al., 1980a), solids concentrations dropped 3 to 4 orders of magnitude within a distance of 100 m (328 ft). Other studies (Houghton, 1981; Ecomar, 1978) found the discharges to be diluted 500:1 to 1,000:1 within 3 m (9.8 ft) of the discharge point, with an additional 100:1 dilution within 100 m (328 ft). In monitoring for the Atlantic COST G-1 well on Georges Bank, in a high energy environment, rapid dilution of drilling discharges also was observed (Environmental Devices Corporation [ENDECO], 1976). Suspended solids ranged from 0.1 to 5.8 mg/l at a distance of 100 m (328 ft) from the discharge point (Houghton, 1981).

Light transmittance values reach background levels at a slightly greater distance from the point of discharge than do suspended solids. This is attributed to the presence of colloidal particles in the water column at levels insufficient to measurably contribute to the suspended solids content but still sufficient to cause detectable light scattering. In the mid-Atlantic, transmittance values reached background levels 800 to 1,000 m (2,624 to 3,280 ft) downcurrent of the source, depending on the rate of discharge. In high-rate (1,000 bbl/hr) tests in the Gulf of Mexico, transmittance values approached background levels at about 500 m (1,640 ft) beyond the point where suspended solids concentrations reached background levels (Ayers et al., 1980a and b).

Soluble components undergo the same general dispersion characteristics as the fine particulate fraction and become well mixed in the water column within a few hours of discharge. Dilution ratios for soluble components have been estimated to be 2 orders of magnitude lower than those of the solids components (Ayers et al., 1980a).

However, within a few kilometers they too would become diluted to undetectable levels and are ultimately lost in the large volume of receiving water (Houghton, 1981).

Trace metal dilution rates, as measured by suspended solids concentrations, have been shown to be similar to that of whole drilling mud dilution rates. Elevated trace metal concentrations in the water column are usually limited to within 1,000 m (3,280 ft) of the discharge point. In a 1,000 bbl/hr discharge test in the Gulf of Mexico, barium, chromium, and aluminum concentrations all approached background levels within 1,100 m (3,608 ft) of the discharge point (Ayers et al., 1980a). However, EG&G (1982) found slight elevations in barium concentrations in sediments as far as 3.2 km (1.9 mi) from the mid-Atlantic well site on Block 684. As part of the Georges Bank Monitoring Program, Bothner et al. (1982) found that barium increased by a factor of 3.5 (from 30 to 107 ppm) in sediments sampled at 200 m (656 ft) from a drill site (Block 410) and by a factor of 2.3 (from 40 to 91 ppm) at a second drill site (Block 312). Smaller increases were observed at 2,000 m (6,560 ft) from the former site and to a distance of 6 km (3.7 mi) from the latter. Within other locations on Georges Bank, however, natural background barium levels in excess of 100 ppm were measured in sediments. No drilling-related changes in chromium concentrations or other metals were observed in bulk sediments at either site. Bothner et al. (1983, 1985) also noted barium increases (5.9 times pre-drilling level) at 200 m (660 ft) from a drilling rig; however, 11 other trace metals were not elevated.

Physiological impacts on marine organisms from drilling muds have been demonstrated in the laboratory. However, many of the tests were conducted using petroleum-contaminated drilling mud samples which are not permitted under NPDES permits to be released offshore. Many toxic properties attributed to drilling muds and cuttings are actually thought to be due largely to the petroleum hydrocarbon content of some of the tested muds (Conklin et al., 1983). In addition, sublethal effects are much more difficult to evaluate than acute toxicities. In most cases, sublethal effects are observed at concentrations of 10 to 1,000 ppm, about 1 to 2 orders of magnitude below $LC_{50}$ bioassay values (NRC, 1983). The NRC (1983) compiled information on bioassay tests from over 70 drilling muds and more than 60 species of marine organisms. This document concluded that most water-based drilling muds are relatively non-toxic.

According to Neff (1987a), of the 5 drilling mud ingredients that make up more than 90 percent of most drilling mud additives used on the U.S. OCS, only chrome (and ferrochrome) lignosulfonate and caustic soda (sodium hydroxide) show even moderate toxicity to marine animals. Sodium hydroxide's toxic effects are due exclusively to pH elevation. However, because of the high buffering capacity of seawater and the rapid dilution expected for this soluble material following its discharge, no biologically significant change in pH occurs when drilling muds are discharged to the ocean. The two main ingredients of drilling muds, barite and bentonite clay, are virtually inert toxicologically, but they can cause damage to marine organisms that are intolerant of suspended particulate material through physical abrasion or clogging. However, even the most sensitive species can tolerate particles for at least a day. Fields studies of drilling fluid dispersion near exploratory rigs in the Gulf of Mexico and off California, Alaska, and New Jersey have shown that concentrations of suspended particles drop 1 to 10 ppm in the drilling mud plume within 1 to 3 hours of discharge. Thus, damage to organisms in the water column from drilling discharges is unlikely.

Studies of acute lethal, sublethal, and chronic effects show that for the majority of used offshore drilling muds examined, concentrations of mud in water lower than 10,000 ppm are not likely to cause serious acute damage (Neff, 1987a). Neff (1987a) also was able to calculate both the time and distance required to render drilling discharges innocuous to organisms living in the water column. Of the species considered, 82 percent would be safe within 11.1 minutes or about 100 m (328 ft) from the discharge (assuming a current speed of 15 cm/sec). This is a conservative estimate since most laboratory toxicity studies consist of exposures lasting much longer than 10 minutes. Field studies on the effects of drilling mud on demersal, benthic, and structure-biofouling communities around offshore drilling rigs corroborate laboratory studies (Neff, 1987a).

Plankton will contact any near-surface discharge of drilling muds and cuttings and will potentially experience (1) increased turbidity and reduced light levels possibly leading to decreased primary production; (2) increased particulate levels possibly causing interference with, or mechanical damage to, filter feeding and respiratory organs; and (3) potential lethal or sub-lethal effects. The magnitude of potential impacts on plankton is related to the total amount of muds and cuttings released, the presence of any toxic substances within the discharges, and whether the discharge occurs at the surface or is shunted below the surface where contact with plankton is minimized. Any factor that increases dispersion is an important mitigating measure; the most important dispersion factors are the magnitude and direction of currents within the water column and water depth (NRC, 1983).

Release of drilling muds and cuttings directly to the sea floor will bury and kill local benthic organisms. It is estimated that about 744 $m^2$ (8,005 $ft^2$) of sediment surface could be covered by up to 1 m (3.28 ft) of drill muds and cuttings at each well during initial drilling (NRC, 1983). Yet, results from the Georges Bank Monitoring Program, which sampled the benthic communities near, upcurrent, and downcurrent from 8 active exploratory drilling rigs for 3 years, did not show any distinct, adverse impacts from exploratory drilling discharges. These studies have specifically shown that there are no long-term changes in benthic infaunal communities that can be attributed to drilling activities (Battelle and WHOI, 1983 and 1985). Additionally, there was no evidence of drilling mud, related hydrocarbon, or trace metal accumulations in the tissues of two Georges Bank epifaunal test species (ocean quahog, *Arctica islandica* and fourspot flounder, *Paralichthys oblongus*), and no significant accumulation of aromatic hydrocarbons was found in sediment further than 2 km (1.2 mi) from the drilling rig (approximately 0.15 ppm aromatic hydrocarbon concentration at 2 km [1.2 mi]) (Payne et al., 1983). Last, of the 12 trace metals measured, only barium increased (to about 5.9 times above the pre-drilling levels) at a station located within 200 m (656 ft) of the drilling rig in Block 410 (Bothner et al., 1983, 1985).

Because the discharge of drilling muds and cuttings will cause turbidity in the waters near the point of discharge, the prey species of fish, marine birds, cetaceans, and sea turtles could be displaced, and the prey-locating ability of predators could be diminished by the presence of mud particles in the water column. However, since the area affected by the discharge plume is small, only predators already in a weakened physical state would experience any effects if they were unable to move to a nearby area where prey is obtainable.

Due to rapid dissipation and dilution, discharges of mud and cuttings are expected to pose little threat to coastal estuaries, wetlands, or submarine canyons. Before reaching these areas, drilling discharges would be so diluted that impacts on the biota would be almost undetectable when compared to natural variations in population characteristics.

## 1.3 Formation Waters

In addition to oil and gas, formation water (i.e., produced water) also is recovered during petroleum production. Formation water is interstitial water present under natural conditions in a geologic formation. The discharge of these waters is subject to EPA NPDES permit regulation. Usually, this water is removed at the production site and disposed of by injection into disposal wells or discharged into the marine environment after treatment.

The amount of formation water recovered depends upon the method of oil and gas production used and the nature of the formation. In some formations, water is recovered in the early stages of production, while in others it may not be recovered until the final stages of a reservoir's production or not at all. Daily discharges from platforms are generally less than 1,590 $m^3$ (10,000 bbl), although discharges from facilities handling a number of platforms are usually larger. Daily discharges of 27,800 $m^3$ (175,000 bbl) have been reported for a central facility in the Gulf of Mexico, and 9,858 $m^3$ (62,000 bbl) for the Trading Bay facility in Alaska (Menzie, 1982). Overall, however, smaller amounts of formation water are produced during the initial production phase, while maximum recovery occurs near the end of a given reservoir's life. In the Gulf of Mexico, an average of 0.8 bbl of formation water is produced for every barrel of oil recovered (DOI, MMS, 1983).

Formation waters contain dissolved inorganic salts in concentrations that vary widely, depending on the formation, but are usually several times greater than that of seawater. The total mineral concentration commonly found ranges from a few ppm to approximately 300,000 ppm in a heavy brine, with typical concentrations ranging from 80,000 to 100,000 ppm (Menzie, 1982). The most common chemical constituents found in formation waters are iron, calcium, magnesium, sodium, bicarbonate, sulfates, and chloride. The formation water properties which may adversely affect the marine environment are entrained oil or petroleum hydrocarbons, high trace metal concentrations, and low dissolved oxygen concentrations.

Petroleum hydrocarbons are present in formation waters at concentrations which vary widely with geographic region and production stage of the formation. However, EPA requires that formation waters be treated prior to discharge so that the concentration of oil does not exceed 72 mg/l for any 1-day period nor exceed 40 mg/l for an average 30-day concentration period (40 CFR 435). Statistical analyses by EPA show an average formation water oil content of 25 ppm for the Gulf of Mexico (DOI, MMS, 1983). Treatment usually consists of processing the water through an oil separation system.

Formation water is characteristically anoxic or low in dissolved oxygen and of a somewhat warmer temperature (30 to 40 °C [86 to 104 °F]) in the Gulf of Mexico than the water surrounding the platforms (Galloway, 1981). Because of rapid dilution, both dissolved oxygen and temperature gradients would likely be rapidly diminished (Koons et al., 1977).

Tillery (1980) reported that concentrations of trace metals in formation waters from the Buccaneer Field in the Gulf of Mexico were higher than the receiving water and that they varied with time (Table 1.3-1). Mercury, strontium, and thallium concentrations in formation waters exceeded seawater concentrations by factors less than ten; barium, cadmium, chromium, and manganese exceeded seawater concentrations by factors of 10 to 100; and iron by factors of 560 to 2,340, although these iron measurements have been disputed (Menzie, 1982).

Formation water is diluted very rapidly following discharge. Consequently, significant elevations in salinity or concentrations of hydrocarbons or metals, or decreases in dissolved oxygen usually are not observed at distances greater than 100 to 200 m (328 to 656 ft) from the discharge. Because of this rapid mixing with sea water, most physical/chemical features of formation water do not pose a hazard to water column biota. However, the low molecular weight aromatic hydrocarbons and some metals in formation waters are toxic and the toxicity of the soluble organic fraction is unknown.

Table 1.3-1. Ranges in mean concentration of metals in produced water and seawater from the Buccaneer Field during summer and winter 1979 sampling periods

| Metal | Range in Produced Water (ug/l) | Range in Seawater (ug/l) | Factor by which Produced Water Exceeds Seawater |
|---|---|---|---|
| Barium | 2.40-10.4 | 0.121-0.259 | 20-40 |
| Cadmium | 0.160-2.06 | 0.037-0.050 | 4-41 |
| Chromium | 0.879-0.970 | 0.051-0.106 | 9-17 |
| Iron | 2,874-2,901 | 5.14-1.24 | 560-2,340 |
| Mercury | 0.076-0.239 | 0.032-0.094 | 2-2.5 |
| Manganese | 2.69-5.90 | 0.064-0.073 | 42-81 |
| Strontium | 191-269 | 46.5-53.7 | 4-5 |
| Thallium | 0.088-0.225 | 0.027-0.053 | 3-4 |

Source: Menzie, 1982.

Practically no laboratory studies have been performed on the sublethal or chronic effects of formation water in marine organisms (Neff, 1987b). However, a field study reported by Rose (1981) from the Buccaneer Oil Field in the Gulf of Mexico demonstrated low toxicity of formation water concentrations in the water column surrounding an outfall. Lagrangian (exposure-time-dependent) assessments of aquatic hazards showed concentrations of formation waters to be 4 orders of magnitude lower than bioassay-based-limiting permissible concentrations. Forty-eight hours after discharge, concentrations of formation water in the water column were about 0.1 mg/l to 0.001 mg/l, while limiting permissible concentrations were held to be 50 mg/l. Consequently, it was concluded that the discharge of formation water does not represent an unacceptable toxicological hazard to planktonic organisms. Eulerian (exposure-time-independent) assessments showed concentrations of formation waters to be approximately 4 mg/l at 140 m (459 ft) from the platform, indicating that toxicity-related hazards to nonplanktonic organisms are unlikely to exist beyond 100 m (328 ft) from the outfall, and may occur only within a few meters.

Formation water may contain small amounts of radionuclides, primarily in the form of radium ($^{226}$Ra and $^{228}$RA). The radium apparently is derived from the normal concentrations of uranium and thorium associated with the clay minerals and quartz sands that constitute the matrix of the hydrocarbon/water reservoir (Neff et al., 1987). To date, there have been no published reports of laboratory studies on bioaccumulation of metals, such as these radionuclides, from formation waters by marine organisms (Neff, 1987b). Studies done on Gulf of Mexico oil field production waters have shown radionuclide levels up to 4 orders of magnitude higher than levels found in open ocean surface waters. Despite these higher levels in formation water as compared to open seawater, there seems to be no apparent human health or environmental contamination problem because of the rapid dilution of these formation waters when discharged offshore (DOI, MMS, 1983).

According to Neff (1987a), any metals or hydrocarbons in discharged formation waters might have a transitory near-field impact on water column organisms but rapid dilution will prevent significant area-wide ecological impact. Some of the metals and hydrocarbons will adsorb to suspended particles in the water column and settle to the bottom where they may accumulate in bottom sediments possibly leading to localized impacts on benthos.

### 1.4 Other Discharges or Sources of Pollution

Deck drainage includes all effluents resulting from platform washings, deck washings, and runoff from curbs, gutters, and drains, including drip pans and work areas. Constituents of concern in effluents are oil and grease. NPDES permit regulations specify there should be "no discharge of free oil" in deck drainage which would cause a film, sheen, a discoloration on the surface of the water, or a sludge or emulsion to be deposited beneath the surface of the water (40 CFR 435). In compliance with this requirement, contaminated deck drainage is collected by a separate drainage system and treated for solids removal and oil/water separation. Separated oil is held for onshore disposal.

Treated domestic waste (e.g., sinks, showers) and sanitary (sewage) wastes are discharged from offshore oil and gas facilities. It is estimated that 6,000 gpd of domestic/sanitary wastes are discharged from a typical exploration vessel and 5,000 gpd from a development platform (DOI, MMS, 1979).

Sanitary discharges are regulated by the EPA and are addressed in MMS regulations (30 CFR 250). Treated effluent must not contain any constituent in concentrations which exceed EPA criteria and must have a minimum chloride residual of 1.0 ppm, and is maintained as close to this concentration as possible (40 CFR 435). This eliminates the potential for generation of more than trace quantities of chlorinated compounds. These sanitary waste effluents are rapidly dispersed and diluted in the water column. Impacts on water quality would consist primarily of an increase in suspended solids (organic material) and accompanying biological oxygen demand (BOD), resulting in a slight decrease in dissolved oxygen (DO) levels in the water column. Impacts from these discharges would be localized near the point of discharge with all pollutants rapidly being diluted and dispersed in the receiving waters.

Hydrogen sulfide ($H_2S$) is found in solution in some crude oil and thus may be encountered during oil and gas drilling operations. Release of this $H_2S$ into the atmosphere can cause serious health effects for rig personnel and may cause metal fatigue to rig equipment. Recognizing the potentially serious consequences of $H_2S$ contamination, MMS has strict controls in force (30 CFR 250.33) to detect and control $H_2S$ related to offshore oil and gas operations.

## 2 OIL SPILLS IN THE MARINE ENVIRONMENT

Oil spills are a major concern in the exploration, development, and production of offshore oil and gas. Unfortunately, the potential harm to the physical, biological, and economic environments, cannot be readily predicted. Some spills, depending on the conditions, can be harmful while others do not seem to significantly affect vulnerable resources.

Oil spills vary both in size and in the damage they cause to the environment. Some spills, such as fuel spills associated with fishing, cargo, or other ocean vessels are chronic, usually small in volume, and almost unavoidable. Other spills can be massive. The *Ixtoc I* oil well blowout in the Gulf of Mexico's Bay of Campeche spilled an estimated 3.1 MMbbls of oil in approximately 10 months, thus becoming the largest spill in the history of exploration for hydrocarbon resources. Assuming a constant rate of discharge, the *Ixtoc I* spill amounted to approximately 310,000 bbl of oil per month. On a weekly basis, this was about twice the amount of oil spilled by the *Argo Merchant* in 1976 in the Nantucket Shoals area off the eastern United States--the largest tanker spill in U.S. waters (NRC, 1985).

Most large spills are caused by sources other than well blowouts. Over a 2-week period, the tanker *Amoco Cadiz* spilled 20 to 25 times the amount of oil off the coast of Brittany, France than did the 1969 oil well blowout in the Santa Barbara Channel off California in 1 month. Because of conditions at the time these two spills occurred, they both resulted in substantial short-term damage to biological and economic resources (NRC, 1985).

The time of a spill is of utmost importance in determining the extent of impacts (University of Rhode Island and Applied Science Associates, Inc., 1982), as are location, weather conditions at the time of the spill, and characteristics of the spilled substance. For example, the barge *Florida* spilled approximately 4,100 bbl of No. 2 fuel oil into Buzzards Bay off Fassett's Point, West Falmouth, Massachusetts during September, 1969. Even though this spill was relatively small in comparison to those mentioned above, the prevailing south to southwesterly winds in this region created an oil-in-water emulsion which spread over more than 1,000 acres of Wild Harbor River, causing immediate large-scale mortality of marine animals in the intertidal and subtidal zones of the river (Sanders et al., 1980). This is an example of the unpredictability of the potential impact of a spill.

### 2.1 Sources of Oil Pollution

Oil pollution results from both natural and anthropogenic (man-made) sources. Although natural seepage may contribute to oil pollution, those hydrocarbons introduced to the ocean as a result of man's activities raise the greatest concern. Both accidental and intentional discharges are sources of pollution. Sources of anthropogenic input include coastal industrial discharges, waste disposal, urban and river runoff, accidental transportation losses and routine discharges, and offshore oil and gas activities. Based on estimates for sources of petroleum input to the marine environment (NRC, 1985), less than 2 percent is the result of offshore oil and gas production.

Most offshore spills are the result of tanker and barge accidents, but pipeline and platform accidents (i.e. well blowouts, explosions, and fires) occasionally contribute to the total. Although the largest oil spill in U.S. history was that of the *Argo Merchant* tanker which ran aground southeast of Nantucket Island, Massachusetts in 1976, and spilled a total of 7.7 million gal (roughly equivalent to 180,000 bbl) of No. 6 fuel oil (Grose and Mattson, 1977; NRC, 1985); there has never been an oil and gas exploration or production-related spill of any significant size in the Atlantic OCS Region. Most spills have been similar to the spill from the drillship *Glomar Pacific* when it was struck by a work boat during a period of rough seas, spilling approximately 100 gal of diesel fuel into the ocean in December, 1978 (Cotton, oral comm., 1988). Several other spills (less than 5 bbl each) have also been reported. Due to the small size and relatively small number of spills, no long-term effects were observed.

For all phases of OCS oil field development in the United States, Gulf of Mexico records represent the most extensive data base for petroleum inputs into the marine environment. According to Gulf of Mexico data (DOI, MMS, 1986 and 1988a), most spills from OCS activities are accidental and small. Only 87 of the 9,655 oil spills on the Gulf of Mexico OCS between 1964 and 1983 were greater than 50 bbl. The majority of oil spills greater than 50 bbl have been the result of pipeline accidents involving dragging anchors or have been relatively small leaks of unknown cause.

Blowouts can occur during well drilling, completion, or production operations. However, most oil spillage from well- or platform-related sources result from producing wells, not from wells being drilled. In fact, only 0.64 percent of all exploratory wells drilled on the U.S. OCS have resulted in blowouts (Martin, 1986). For the period of 1971 through 1986, the MMS has estimated that only 840 bbl of crude oil and condensate were spilled due to blowouts resulting from oil and gas operations along the entire U.S. OCS (DOI, MMS, 1988b). Martin (1986) also calculated that the probability of a U.S. OCS exploration well blowout resulting in an oil spill of $\geq$1,000 bbls is 0.0 with a 95 percent confidence level of 0.04 percent. Production platform accidents, other than blowouts (such as holding tank overflow because of equipment malfunction or fires) have resulted in spillage of oil and, on occasion, abandonment of platforms (DOI, MMS, 1983).

Accidental oil spills from tankers and barges, as well as oil discharged during normal vessel operations (operational discharges), are the largest source of oil spills. It has been estimated that for most years, the total input of oil into Atlantic east coast waters by vessel operational discharges (bilge water pumping and tank cleaning and ballasting) far outweighs accidental spills. For the year 1979, it was estimated that the oil input to the east coast area (4.8 to 644 km [3 to 400 mi] offshore) by operational discharges unrelated to offshore oil and gas operations was 4.3 million gal (approximately 102,000 bbl) (DOC, NOAA, 1984).

With the enactment of the 1978 Port and Tanker Safety Act (P.L. 95-474) and the 1980 Act to Prevent Pollution from Ships (P.L. 96-478; effective on October 2, 1983), the Coast Guard has promulgated stringent requirements (33 CFR 151-157 and 46 CFR 30) directed at preventing marine pollution from both accidental and operational discharges by tank vessels carrying oil and hazardous materials in bulk. These regulations require a variety of safeguards including such items as vessel construction standards, navigation procedures, and limitations on operational discharges (e.g., in reference to oil-tainted ballast water and refuse).

## 2.2 Fate and Effects of Oil in the Offshore Marine Environment

Petroleum hydrocarbons fall into three major categories--the alkanes, or aliphatic hydrocarbons, consisting of the fully saturated normal alkanes (paraffins) and branched alkanes; the cycloalkanes, or saturated ring structures, also called cycloparaffins or napthenes; and the aromatic compounds containing one or more (benzene) rings connected as fused rings (e.g., napthalene) or lined rings (e.g., biphenyl). Crude oils from different sources can differ appreciably in percentage composition of the various hydrocarbon fractions. Consequently, the possibilities for combined chemical types are enormous, resulting in extremely complex mixtures of varying toxicity to marine life (NRC, 1985).

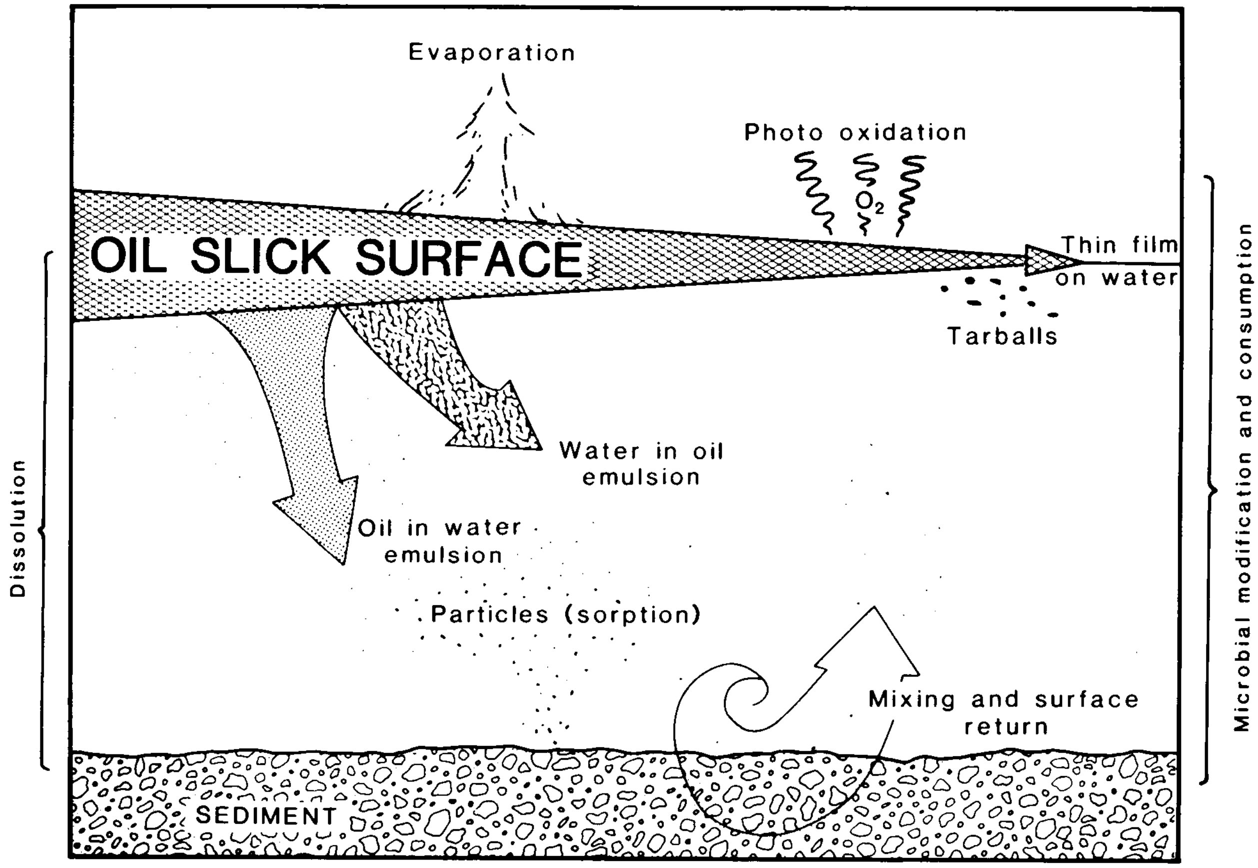
Non-hydrocarbon components of oil, which include compounds containing sulfur, nitrogen, oxygen, and trace metals, generally range from 0 to 15 percent. Trace metals are present in very small concentrations (ppm range) with nickel and vanadium usually found in the largest proportion and cobalt, mercury, iron, and manganese present in smaller amounts (Connell and Miller, 1980; DOI, BLM, 1979).

The impact of oil spills in the marine environment is largely dependent on the type and proportion of the oil's chemical components and how the components change as the oil weathers. In turn, the weathering ("aging") process is largely depend on oceanographic and meteorologic factors at the time of, and following, the spill.

Weathering involves a number of physical and biochemical processes which change the chemistry and reduce the concentration of oil in the environment. These processes include evaporation, dispersion, dissolution, emulsification, biodegradation, photo-oxidation, and sedimentation. Eventually, weathering leaves a tar-like residue which breaks up into tar lumps or tar balls. Various weathering processes and transport pathways of spilled oil at sea are depicted in Figure 2.2-1; their relative importance is shown in Figure 2.2-2.

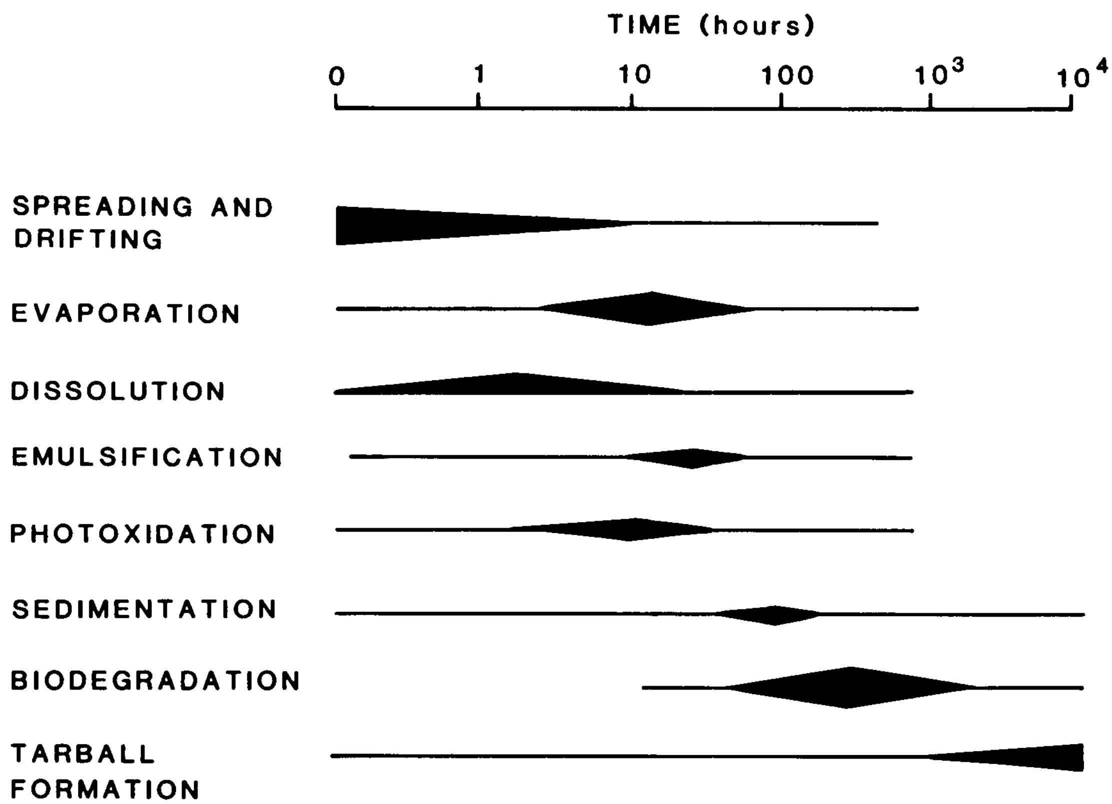
When oil spills onto water, a surface slick forms because of the low water solubility of most oil components. Currents, waves, and winds then act to spread the oil slick into thin films, but the extent of spreading is dependent on the physical and chemical nature of the particular oil (Lee, 1980; NAS, 1975; and NRC, 1985). Spreading makes the oil much more susceptible to immediate evaporation of the more toxic and volatile lower-molecular-weight hydrocarbons (e.g., benzene, toluene) from the surface film. The amount of oil that evaporates depends on the extent of spreading, ambient temperature, wind speed, solar radiation, and composition of the oil. Within a few days, evaporation could remove up to 50 percent of the oil, depending on environmental conditions (e.g., rough seas would tend to increase evaporation rates) (NAS, 1975; and NRC, 1985). During the *Ixtoc I* oil well blowout in the Gulf of Mexico, low-molecular-weight hydrocarbons evaporated or were burned at the ocean surface immediately after escaping from the well, resulting in a nearly equivalent loss of saturated and aromatic hydrocarbons (Boehm et al., 1981; Golob and McShea, 1981; NRC, 1985). During the North Sea *Ekofisk Bravo* oil well blowout, 35 to 40 percent of the lighter hydrocarbon components of the oil evaporated immediately. Of the remaining hydrocarbons, 50 percent had evaporated after 12 hours and 68 percent had evaporated after 15 days (Haegh and Rossemyr, 1980). Similarly, during the tanker *Amoco Cadiz* spill off the coast of Brittany, France, evaporation was an important weathering process for all of the low-boiling components of the oil, including aliphatic and aromatic compounds. More than 40 percent of the remaining compounds, with molecular weights less than n-$C^{12}$, were lost per day, and residence times from 2 to 5 days were calculated for compounds below n-$C^{15}$ (Jordan and Payne, 1980).

Dissolution of the low-molecular-weight, more toxic and soluble hydrocarbons, would occur simultaneously following a spill. However, since only about 1 to 5 percent of spilled oil generally goes into solution, evaporative processes would still predominate




Source: Boehm, 1982

Figure 2.2-1. Schematic Showing Weathering Processes and Transport Paths of Oil Spills




Source: Koons and Wheeler, 1977; Wheeler, 1978

Figure 2.2-2. Relative Importance of Various Processes Affecting Oil in the removal of hydrocarbon components from sea water. The rate of dissolution for the various hydrocarbon components would depend on complex interactions between chemical properties inherent in the oil and in environmental factors (e.g., turbulence, salinity, temperature). Generally, dissolution would be a significant process only within the first several hours after a spill.

The ultimate loss from the spilled oil by evaporation and dissolution for the *Ixtoc I*, *Uniacke G-72*, and *Ekofisk Bravo* blowouts was close to 70 percent. Although components up to n-$C^{22}$ were reduced, some of this loss may have been a result of photochemical and microbial degradation (Haegh and Rossemyr, 1980).

The agitation of oil slicks by wave and surf action supplies the energy to form small droplets of stable emulsions from 5 micrometers to several millimeters in size. Such droplets are then pushed into the water column and dispersed (NRC, 1985). Dispersion of a surface slick is an important process in determining the lifetime of the slick. Droplet formation increases the surface area of the oil, thereby increasing the rate of physical, chemical, and biological processes affecting weathering.

Water-in-oil emulsions, also known as "mousse," weather slowly because of the relatively small proportion of water and the limited supply of oxygen available for microbial degradation (Connell and Miller, 1980; NAS, 1975; and NRC, 1985). This stable emulsion, which forms from within a few hours to a few days after an oil spill, floats on the water surface and eventually can be carried ashore by wind and waves. If there is strong, turbulent mixing, it could be driven into the water column.

Shortly after contacting the sea surface, oil from both the *Ixtoc I* and *Ekofisk Bravo* blowouts formed viscous emulsions of approximately 70 percent water and 30 percent oil--similar to the emulsion formed following the *Amoco Cadiz* spill. Weathering of the *Amoco Cadiz* oil mass was accelerated by formation of a sheen in the surface microlayer of the mass which then underwent a greater degree of evaporation and/or photo-oxidation than the underlying mass. Oil entering the water, however, column remained there for significant periods of time, depending on droplet size, buoyancy of the oil, and water column hydrography. Oil spilled at or near the water surface would generally tend to remain in the surface layers of the water column. However, whole oil in the form of mousse or tar could become heavier than the surrounding water and sink (Boehm et al., 1981; Golob and McShea, 1981; Haegh and Rossemyr, 1980; NRC, 1985; and Walter and Proni, 1980).

Under the circumstances of a subsurface release of oil, as may occur from a pipeline rupture or an undersea well blowout, a subsurface oil plume may form. The *Ixtoc I* blowout occurred in approximately 48 m (157 ft) of water with a significant quantity of the released oil forming a subsurface plume of droplets which were suspended in a mixed layer at a depth of 5 to 20 m (16.4 to 65.6 ft). Within 5 km (3.1 mi) of the wellhead, the subsurface plume was made up of oil droplets greater than 0.45 microns and had petroleum hydrocarbon concentrations greater than 600 parts per billion (ppb). Such whole oil was found at concentrations greater than 20 ppb at 20 m (65.6 ft) depths within 25 km (15.5 mi) of the well. Although there appeared to be other unidentified processes controlling the movement of the surface slick, the subsurface plume was, for the most part, aligned with the surface slick (Boehm and Fiest, 1982; Fiest and Boehm, 1980; NRC, 1985; and Walter and Proni, 1980).

Water samples taken from the *Ixtoc I* subsurface plume were considerably enriched in light aromatic hydrocarbons relative to other aromatic components, probably due to the presence of considerable quantities of soluble, solubilized, or colloidal material in the water. The fact that the subsurface oil could be characterized by a different chemistry and weathering regime implies that the subsurface oil was a "fresh" oil plume which had remained subsurface since its discharge and in which evaporative loss of aromatics was greatly decreased (Boehm and Fiest, 1980). Of particular importance is the fact that concentrations of some of the more toxic components appeared in the water column in increased concentrations. According to Boehm and Fiest (1980), the concentrations of individual hydrocarbons in the dissolved fraction (0.01 to 3 ppb) in the water column following the *Ixtoc I* blowout appeared to lie below the toxic range, even in the acute impact zone. However, the total concentration of waterborne low-molecular-weight aromatics (alkyl benzenes and naphthalene compounds) in water fell in the 0.5 to 500 ppb range, and concentrations of total waterborne oil dispersions were in the 100 to 10,000 ppb (0.10 to 10 ppm) range.

The sedimentation process following a spill is characterized by oil associating with particulate material in the water column. For example, in the case of the *Ixtoc* I blowout, there were several instances of particulate-bound oil where surface slicks were not readily apparent (Payne et al., 1980). To explain this, it was hypothesized that once oil had been adsorbed onto particulates, it was then subject to subsurface horizontal and vertical advective transport, and it could be transported a considerable distance before settling to the bottom. Payne et al. (1980), reviewed the literature and found that particulate/oil interactions are a dominant process in the ultimate disposition of petroleum.

This is not an important process in most open ocean areas with relatively low concentrations of suspended particles and dynamic oceanographic forces. However, sedimentation processes within coastal or other shallow areas could quickly remove dispersed oil from the water column to the bottom by adsorption onto the high concentrations of clays, fine suspended sediments, or detrital particles. Zooplankton fecal pellets also have been found to transport ingested oil droplets to the bottom sediments (Geyer, 1980). Lee (1980) states that "bottom sediments are the ultimate sinks for undegraded oil." However, just as sedimentation may remove oil from the water column, sediment resuspension (e.g., during a storm in shallow water) can reintroduce the oil into the water column.

The processes discussed up to this point distribute oil spilled within the marine environment into different phases (i.e., air or water) but do not actually degrade the oil. This is accomplished primarily by photo-oxidation and microbial degradation.

During photo-oxidation, energy from sunlight in the presence of oxygen transforms hydrocarbons into oxygenated compounds (e.g., carboxylic acids, benzoic acid, alcohols, ketones, and phenols) which produce highly soluble end products in the water column below the slick. Laboratory studies have found some of these products to be more toxic than the original products, and some (polycyclic aromatic hydrocarbons) have been found to be carcinogenics (NRC, 1985).

Because of the time needed for initiation of significant microbial degradation of oil slicks, which generally have short lifetimes, it is assumed that microbial degradation is less important than other processes in removing an oil slick. However, once the oil is dispersed into fine droplets or particles in the water or deposited on sediment, microbial degradation becomes of great importance (Lee, 1980; NRC, 1985). Microbial action transforms hydrocarbons to more soluble oxidized products. Microbial degradation played an important role in the weathering of oil spilled during the *Amoco Cadiz* incident (Gundlach et al., 1983). In comparison, however, biodegradation was nearly inoperative in the open ocean following the *Ixtoc I* spill and appeared to be related to low concentrations of nutrients in the underlying water (Atwood and Furguson, 1982).

Even after evaporation, dissolution, emulsification, photo-oxidation, and microbial degradation of an oil slick, a viscous residue remains. From this residue, tar lumps or tar balls form in the water column. Tar balls generally contain higher-weight hydrocarbons and oxygenated sulfur-containing compounds (e.g., asphaltenes). As much as 20 percent of a crude oil spill could remain as such a residue, and since tar balls are resistant to microbial degradation, their lifetime could be on the order of several months to several years (Geyer, 1980; NRC, 1985).

Oil from the *Ixtoc I* spill persisted as tar reefs for long periods along the Texas coast. It was estimated that at one time, 5 to 10 percent of the petroleum hydrocarbons existing as pelagic tar in the eastern Gulf of Mexico originated from *Ixtoc I*. But, at least 50 percent of the pelagic tar in the eastern Gulf of Mexico is thought to have originated from the operational discharge of crude oil tanker washings (*Oil Spill Intelligence Report*, Vol. VI, No. 24, June 24, 1983).

If a major spill occurred at the water surface in the open ocean, water quality degradation could be initially severe, although most likely only temporary. Oceanic processes would assist in breaking up any resulting slick and would contribute to weathering the oil through photochemical oxidation and biological degradation. In the unlikely event of a subsurface oil spill due to a wellhead blowout on the ocean floor, some oil could be forced into the sediments. However, most of the oil would rise to the surface, would weather, and would behave like a surface spill. Major spills in, or reaching, shallow coastal waters would have the greatest impacts. Although most of the more toxic compounds in oil escape into the atmosphere very quickly, a large spill occurring in a low-energy, poorly-circulated regime close to shore (e.g., an estuary or embayment) could result in the spilled oil and/or weathered products being dispersed throughout the shallow (<60 m [197 ft]) water column and trapped within the sediments (NRC, 1985).

Studies on the biological effects of oil spills on plankton have demonstrated no mass toxic effect in the field, either from a spill or chronic input conditions. In addition, there have seldom been significant prolonged changes in open-water zooplankton populations and communities experiencing acute spills or chronic discharges. Both types of plankton appear to recover and maintain themselves, possibly because of their wide distribution and rapid regeneration rates (NRC, 1985).

Most of the clearly documented effects of spilled oil on benthic ecosystems are associated with nearshore spills rather than with those in offshore areas. The small amount of evidence available suggests that oil concentrations in sediments offshore remain sufficiently low and cause little harm. After the *Argo Merchant* spill, very little oil could be found in the bottom sediments or benthic fauna of Georges Bank or Nantucket Shoals, except in the immediate vicinity of the wreck. Similarly, there was little evidence of much accumulation of oil in the sediments from the *Ekofisk Bravo* blowout in the North Sea in the few weeks following the spill, even though sediment-trap studies showed sedimentation of oil (Howarth, 1987).

It is difficult to generalize about the effect of oil spills on benthos because there is so much variation among the genera and species as well as among the various life-cycle stages of any one species. However, benthos of the intertidal zone, especially those found in lagoons, embayments, estuaries, marshes, and tidal flats are very sensitive to hydrocarbons. In addition to the toxic effects of high concentrations of oil, there is also the physical threat of smothering benthos under a blanket of viscous oil. Sublethal effects have been observed in all types of benthos and include alterations in respiration, growth, reproduction, and behavior. Most of this information, however, comes from laboratory studies rather than actual oiling in the field. Offshore and deep water benthos would be impacted to some degree by oil spilled into the water column and transported to the bottom (NRC, 1985).

The effects of an oil spill on fishery resources is highly variable. Oil spills have been shown to kill adult fish, contaminate fish and shellfish, reduce the growth of fish and shellfish, and perhaps decrease fish recruitment (Howarth, 1987). Teal and Howarth (1984) suggest that although adult fish can be killed by oil spills, this probably poses less of a threat to commercial fisheries than does damage to eggs and larvae, or changes in the ecosystem supporting the fishery. Therefore, true assessment of impacts may have to wait for a long-term assessment of population changes stemming from any initial egg and larvae mortalities. Egg and larvae mortalities are critical because these early life stages are often planktonic and, therefore, unable to avoid spills. In addition, toxicity thresholds are lower at these stages. Adults are not resistant to the effects of an oil spill; they exhibit greater toxic resistance and responses rather than direct mortality. Such responses to oil spills often include avoidance behavior (Nelson-Smith, 1973; Weber et al., 1981) or sublethal responses, which are difficult to evaluate. However, animals, such as shellfish, cannot avoid oiled waters and some others, such as blue crabs, may not necessarily avoid oiled sediments (Olla et al., 1980). There is even some evidence suggesting that fish do not always avoid areas of contamination (Blumer et al., 1971; Gooding, 1971). Studies of actual open-water spills have concluded there has been no reduction detectable in fishery harvests as a result of these spills (MacIntyre, 1982; Sherman and Busch, 1978; NAS, 1985). However, a result of the enormous *Amoco Cadiz* tanker spill was the disappearance of the 1978 year class of sole (*Solea vulgaris*) and plaice (*Pleuronectes platessa*) from contaminated areas of northern Brittany, but subsequent year classes returned (Davis et al., 1984).

Oil spill effects on marine mammals, sea turtles, and birds can be categorized as direct and indirect. Direct impacts include contact and coating of the animal with oil, potentially causing the loss of insulation, altering buoyancy, and inhibiting swimming/flying abilities; ingestion of oil; and interference with physiological behavior due to olfactory or vision disturbances. The result or severity of these impacts would depend on such factors as length of exposure to spilled oil, ambient water and air temperature, whether the spill remained at sea or approached shore, the habitat of coastal and shore birds, and overall physical condition of the animal. Ingestion and accumulation of oil via preening of skin or feathers and feeding on oiled prey could lead to reproductive failure and increased physiological stress reducing the ability to survive. During the bird's nesting season, oiled adults can transfer oil from their plumage to the nest, eggs, or chicks, and thereby reduce hatching and fledgling success (Biderman and Drury, 1980).

An oil spill reaching sensitive coastal estuaries, tidal wetlands, or beaches would have potentially severe impacts because of the complex and fragile nature of these ecosystems. Non-weathered oil entering a bay or estuary, striking the shoreline, and/or becoming incorporated into bottom sediments would represent a serious impact on water quality and aquatic life. Since water-flow patterns in estuaries tend to make these habitats act as nutrient and pollutant traps, spilled oil could be slow in flushing from the system, increasing the exposure of many estuarine plants and animals to potentially dangerous levels of hydrocarbons. The effects of a major oil spill on the many biological resources of these areas (such as birds, commercial fish, shellfish, their larvae and juveniles, and other aquatic invertebrates) would be severe.

The possibility of a spill depositing significant amounts of oil in a submarine canyon environment is remote because any descending spilled oil would lose most, if not all, of the more volatile (and therefore more toxic) components before descending to the canyon depths. Therefore, spilled oil poses only a minor threat to canyon biota.

# 3 OIL SPILL CLEANUP AND CONTINGENCY PLANNING

## 3.1 National Oil and Hazardous Substances Pollution Contingency Plan

The National Oil and Hazardous Substances Pollution Contingency Plan (NCP or Plan) is required by section 105 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); 42 U.S.C. 9605; and by section 311(c)(2) of the CWA, as amended; and 33 U.S.C. 1321(c)(2). The Plan provides for a coordinated and integrated response by departments and agencies of the Federal Government to protect the environment from pollution. It specifies the division of responsibilities among the Federal, State, and local governments in response to an oil or hazardous substance discharge. The following Federal Agencies and Departments are charged with implementing the Plan: Agriculture, Commerce, Defense, Energy, Health and Human Services, Federal Emergency Management Agency, Interior, Justice, Labor, State, Transportation, and the Environmental Protection Agency. Each of these participating Departments and Agencies provides expertise consistent with their capabilities and legal authority.

The NCP establishes requirements for the National Response Team (NRT) and its regional counterpart the Regional Response Teams (RRT's), each consisting of representatives from the twelve participants. The NRT is responsible for maintaining National readiness to respond to a major discharge of oil or release of a hazardous substance. The NRT also reviews incoming reports from the RRTs and reviews regional responses to oil or hazardous discharges. In turn, the responsibilities of the RRTs include region-wide planning and preparedness activities, coordination, and advice during response actions. RRT's work with On-Scene Coordinators (OSC's), the Federal officials who coordinate and direct the Federal response to a release or discharge, to develop regional and local contingency plans.

The Federal responsibility for actual oil spill cleanup is assumed by the EPA for inland waters and by the Coast Guard for spills that occur offshore. Within each region, an OSC has been designated by the Coast Guard or EPA. It is the responsibility of the OSC to insure that a prompt and accurate assessment of the situation is made. The Coast Guard furnishes OSC's for oil discharges threatening the coastal zone, while EPA provides OSC's for releases into or threatening the inland zone, or may designate the Coast Guard as OSC for inland spills. The EPA also assumes all remedial actions resulting from removals initiated by the Coast Guard in the coastal zone, except those involving vessels.

In the event of a spill, the owner of the tanker or facility is responsible for cleanup. The OSC makes a determination as to whether the responsible party is able and willing to combat the spill adequately. Affected States are invited to participate in the deliberation. If the responsible party is taking adequate corrective action, the OSC maintains a role as coordinator. If it is determined by the OSC that an adequate response cannot or will not be made by the responsible party, cleanup activities are undertaken by the Federal Government through the Coast Guard.

The OSC immediately notifies the RRT of any actual or potential major discharge (in coastal waters, 100,000 gal or more). Also, the RRT may be activated during any pollution emergency. As a technical advisory board, the RRT can support the OSC by recommending specific actions in response to the discharge; prepare information releases for the public; request other Federal, State, or local government agencies to provide assistance; and assist the OSC in communications with the NRT.

In addition to the RRT's, other special forces and teams are available to provide support to the OSC. Located at Coast Guard Headquarters in Washington, DC, the National Response Center (Center) is the national communications center for activities related to response actions. The Center receives and relays notices of discharges or releases to the appropriate OSC and disseminates OSC and RRT reports to the NRT. In the event that a national response action is required, the Center provides facilities for the NRT. The regional communication center for pollution emergency response activities is known as the Regional Response Center (RRC). The RRC, whose locations are specified by each regional contingency plan, provides facilities and personnel for RRT operations.

The National Strike Force (NSF) is another resource available to the OSC. Maintained by the Coast Guard, the NSF consists of Strike Teams on the Pacific and Gulf coasts. If necessary, the Strike Teams provide equipment, communications, and personnel support. In addition to acting in an advisory capacity to the OSC, the Strike Teams assist in cleanup operations during any spill determined by the OSC to be a Federal cleanup responsibility. The Coast Guard Strike Force located closest to the Atlantic OCS planning areas is the LANTAREA (Atlantic Area Strike Force) Strike Team based in Mobile, Alabama. Table 3.1-1 contains a list of equipment maintained by the LANTAREA Strike Team.

The Coast Guard districts do not rely primarily on the NSF for pollution response equipment, but use contractor, oil spill cooperative, and local Coast Guard equipment to respond to most spills. The NSF equipment is used to supplement locally available equipment and, when required, and is available via rapid transportation, including air, to the port nearest the spill.

For the *Argo Merchant* spill, which occurred during adverse weather conditions, the response time for the Atlantic Strike Team (predecessor to LANTAREA) to reach the spill site was approximately 7 hours (Coast Guard, written comm., 1981). This quick response time resulted from the relative ease of transporting the offloading pumping system typically used to deal with vessel incidents.

Table 3.1-1. Coast Guard LANTAREA Strike Team equipment stockpile

| Item | Description | Quantity |
|---|---|---|
| Offshore Devices, Inc. Skimming Barrier | Containment/skimming | 8 |
| Air Deliverable Anti-Pollution Transfer System | Vessel Cargo offloading | 6 |
| Dracone Flexible Barge | Recovered oil storage | 7 |
| Viscous Oil Pumping System | Recovered oil storage | 2 |

Source: Coast Guard, oral comm., (1988).

## 3.2 Oil Pollution Compensation Fund

Title III of the OCSLA, as amended, establishes an Offshore Pollution Compensation Fund in the U.S. Treasury, administered by the Secretaries of Transportation and Treasury. This is a spill liability fund which provides compensation for economic loss, including removal costs, resulting from oil pollution from an offshore facility or vessel. The Fund covers spills from any offshore facility as well as any vessel transporting oil directly from such a facility.

Money for the Fund is generated by fees levied on OCS-produced oil (not to exceed 3 cents per barrel produced). The Secretary of Treasury has the authority to modify the fees to insure that the Fund is maintained at a level between $100 and $200 million. The Fund is reimbursed by claims against liable operators or owners of the vessel or facility responsible for the oil pollution or, in some cases, a threat of oil pollution. Except in cases of willful misconduct or gross negligence, total liability is limited to $250,000 or $300 per gross ton per vessel, whichever is greater; for an offshore facility, liability is limited to the total cost of cleanup and removal and $35 million in damages.

Claims against the Fund may be made for economic loss resulting from oil pollution. For instance, claims for economic loss may result from the removal costs, for damages caused by the oil, and for loss of income or tax revenues. The economic loss may be due either to injury to or destruction of real or personal property or natural resources, or the loss of use of real or personal property or natural resources. The funds may be used to restore, rehabilitate, or acquire the resource areas equivalent to those damaged. Claims may be made by any U.S. resident, the Federal Government, and any State or political subdivision thereof. In some circumstances, claims for economic loss also may be made by foreign claimants. Claims must be submitted in writing to the Fund within 3 years of discovery of the economic loss for which compensation is sought.

## 3.3 Industry Oil Spill Contingency Plans

Guidelines addressing oil spill control, including containment and cleanup are listed in the OCS regulations (30 CFR 250) under Subpart C--Pollution Prevention and Control. It is the responsibility of the lessee to control and remove oil spilled as a result of operations conducted by or on behalf of the lessee. All oil spills of one barrel or less must be reported to the appropriate MMS District Supervisor within 12 hours. Spills of greater than one barrel must be reported immediately and confirmed in writing.

A lessee is required to submit an Oil Spill Contingency Plan (OSCP) for approval with or prior to submitting a Plan of Exploration or Plan of Development/Production. This contingency plan, outlining the availability of spill containment and cleanup equipment and trained personnel, is reviewed and updated annually. The OSCP must assure that full response capability can be committed during an oil spill emergency, including specification of appropriate equipment and materials, their availability, and time needed for deployment. The OSCP also must include provisions for varying degrees of response effort depending on the severity of the spill. Provisions must be established for the following: early detection and timely notification of an oil spill to responsible agencies; specific response actions, including identification of an oil spill response operating team; predesignation of an oil spill response coordinator; preplanned location for an oil spill response operations center; and provisions for disposal of recovered oil and oil contaminated wastes.

MMS has the authority to specify the location, type, and amount of cleanup equipment maintained during offshore drilling. With Coast Guard guidelines suggesting a response to a spill within 6 to 12 hours, MMS can require Atlantic operators to maintain equipment offshore if the required response cannot be met by shore-based operations. A Fast Response Unit or similar equipment may be maintained on the rig or on a work boat with trained personnel for a rapid cleanup response. Additional cleanup equipment may be kept at an onshore storage facility. Table 3.3-1 lists equipment that was stockpiled onshore for spill response during past oil and gas exploration in the Atlantic OCS.

A Memorandum of Understanding (MOU) between the Departments of the Interior and Transportation (see Appendix) outlines the respective responsibilities of the MMS and the Coast Guard regarding the supervision of abatement, containment, and cleanup efforts. The MMS is responsible for the coordination and direction of abatement measures. The operator has the primary responsibility for cleanup; however, the Coast Guard has the responsibility and authority to take control of the cleanup operation if the efforts by the operator are unsuccessful or inadequate.

Table 3.3-1. Typical cleanup equipment and materials

| Equipment | Function |
|---|---|
| Fast Response Unit Model I | Open-sea skimming |
| Fast Response Unit Model II | Open-sea skimming |
| Kepner Open Sea Boom | Oil containment |
| Kepner Sea Boom | Oil containment |
| Goodyear Open Sea boom | Oil containment |
| Boat Spray System | Oil spill dispersing |
| Helicopter Spray System | Collectant dispenser |
| Bird Scare Guns | Bird protection |
| Radio Communications System | Spill cleanup coordination |
| Chemical Dispersant | Oil spill dispersing |

Source: Clean Atlantic Associates (1984).

## 3.4 Oil Spill Containment and Cleanup Capability

The technology for mitigating oil spills has advanced in recent years (Fingas et al., 1979; Byroade et al., 1981; Robertson, 1981; Johnson and Pastorok, 1985; Schulze, 1986; and Murrel et al., 1987). The NCP and the regulatory practices of the MMS provide assurance of response within the limitations of existing technology. However, the physical circumstances surrounding a spill, such as the rate and volume of oil spilled, sea state, currents, and weather conditions may limit the effectiveness of cleanup efforts. The most difficult operating conditions for cleanup equipment are high seas, storms, rapid currents, ice, and problems posed by the rapid formation of water-in-oil emulsions (mousse). Existing shipborne radar is a readily available tool which can mitigate many of the detection problems associated with fog, rain, darkness, and relatively high sea states. A recent study conducted offshore Novia Scotia demonstrated that shipborne radar can detect oil slicks in winds up to 55 km/hr (30 kt), depending on the sea state (Tennyson, 1988).

The appropriate response to an oil spill also depends on the physical and chemical properties of the oil and the extent to which the oil spreads, evaporates, disperses, or forms oil-in-water or water-in-oil emulsions. Many treatment methods exist, including mechanical recovery, chemical dispersal, absorbing, and burning of spilled oil.

A wide variety of cleanup techniques is available for the removal and treatment of oil released into the marine environment. Response measures after a major spill in the open ocean can be broadly classified as either natural cleansing, mechanical recovery (booms, skimmers, or sorbents), or chemical dispersal (dispersants). Booms and skimmers are used primarily for large spills, while sorbents are applicable primarily in the control of small spills. Dispersants may be utilized where the oil slick is threatening areas of major biological, cultural, historical, or recreational importance. In general, weather conditions limit spill control and containment at sea and, depending on the oceanographic conditions, natural cleansing may be the option of choice. Ultimately, the recovery of oil at sea is limited by the sea state. Recent offshore trials of oil spill containment equipment have demonstrated that by operating in a downwind mode to reduce relative boom/water velocities and skimming in the lee of a vessel, recovery operations are possible in seas of 1.5 m (5 ft) and winds in the 37 km/hr (20 kt) range, equivalent to sea state 4 (Buist and Potter, 1988). As waves begin to exceed 1.5 m (5 ft) in height, however, mechanical cleanup becomes ineffectual, while the effectiveness of dispersants and natural dispersion increases. In addition, spills in the open ocean may be far away from logistical bases. For these reasons, containment and cleanup of oil in the open ocean is only marginally effective, with past results ranging between 5 and 15 percent of that spilled (DOI, MMS, 1987).

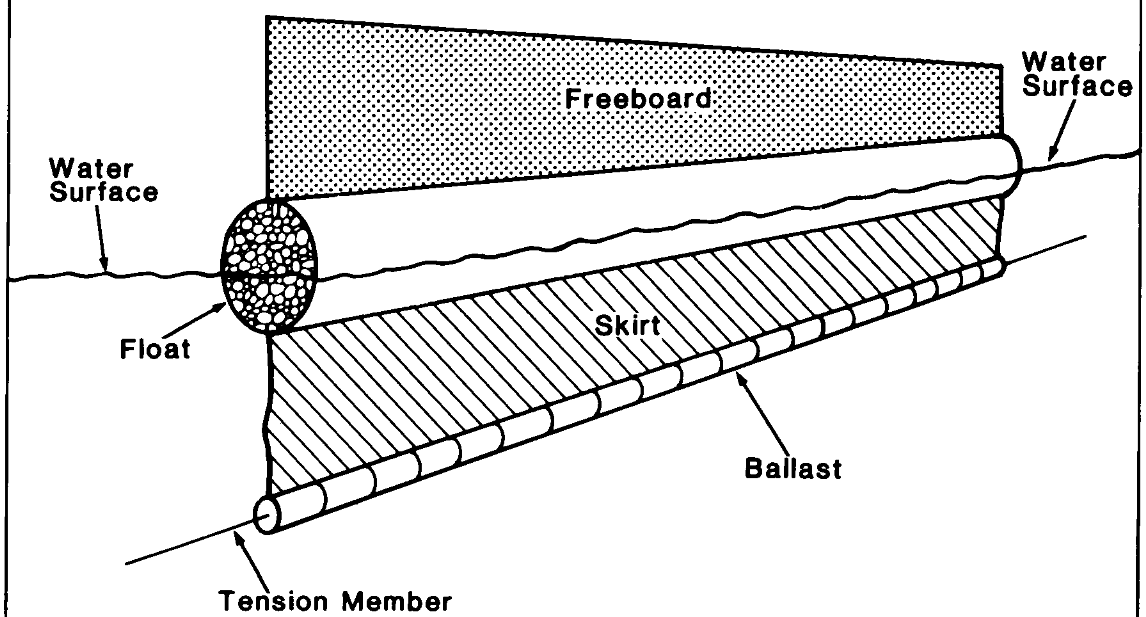
### 3.4.1 Booms

Booms are floating barriers used to prevent the spread of oil over the surface of the water. Constructed of lightweight material, they can be rapidly transported and deployed. In preventing the spread of the slick, they localize the problem, thus, minimizing pollution and making cleanup easier. They can be positioned to concentrate the oil into a thicker layer and direct it toward a skimming device for removal. In addition, they can be deployed to obstruct oil from environmentally sensitive areas. Booms generally have the five operating components listed below (Figure 3.4.1-1)

(1) Float -- Each boom has a flotation element that keeps the boom riding on the surface of the water. Heavier booms require more buoyancy and a larger volume of flotation material.

(2) Freeboard -- The freeboard is the vertical height of the boom above the water's surface. This component contains the slick and prevents oil from washing over the top of the boom.

(3) Skirt -- The skirt is the portion of the boom below the float which helps to prevent oil from escaping under the boom. It is important to maintain the skirt in a vertical position, otherwise oil may pass under the boom.

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Source: Modified from Fingas et al., 1978

Figure 3.4.1-1. Basic Components of a Boom

(4) Ballast -- To maximize containment of the oil, some type of ballast or weight is attached to the skirt to keep the barrier in a vertical position. The ballast may be provided by weights, cables, chains, rods, or water bladders attached to the bottom of the skirt.

(5) Tension member -- The tension member carries horizontal tension loads imposed on the boom. This component often consists of cables, lines, or chains placed along the skirt and/or the freeboard. It is designed to provide structural integrity to withstand winds, waves, and currents during towing and anchoring.

The majority of booms can be classified as either fence or curtain booms. Fence booms are constructed of rigid or semi-rigid material, with the freeboard and skirt combined into a single unit. Curtain booms are constructed of a flexible material which allows the freeboard and skirt to move independently, with the flexible skirt held down by a tension member. Generally, curtain booms are used for open marine cleanup operations (Murrell et al., 1987; Schulze, 1986).

The effectiveness of booms in preventing the migration of an oil slick varies widely. The ambient sea and meteorological conditions and thickness of the slick are the primary determinants of the success of the operation. Failure is usually the result of a combination of sea and meteorological conditions. In rough seas, booms may fail when oil splashes over the top of the boom. Splashover is directly related to several factors--freeboard height, angle of approach of waves to the boom, amount of oil in the boom, and size and interval of the waves. Oil also may be lost under the skirt by drainage or entrainment failure. Drainage occurs when a large pool of oil gathers at the boom. As the pool increases in depth, oil begins to flow down the face of the boom and under the skirt. Entrainment is the loss of oil under the skirt, usually due to a combination of headwave thickness and relative tow speed. At high current velocities, in the range of 1.4 to 2.2 km/hr (0.75 to 1.2 kt), oil passes under the skirt. However, this problem can be mitigated by positioning the boom at an angle to the current.

In general, booms are successful in containing oil in calm water. Under more severe conditions, however, containment failure occurs. In seas greater than 1.5 m (5 ft) only partial containment is feasible, but booms can be effectively positioned to divert oil into an advancing skimmer (Murrell et al., 1987). Offshore booms are useful in international sea states up to 4 (significant wave height to 2.1 m [6.9 ft]).

3.4.2 <u>Skimmers</u>

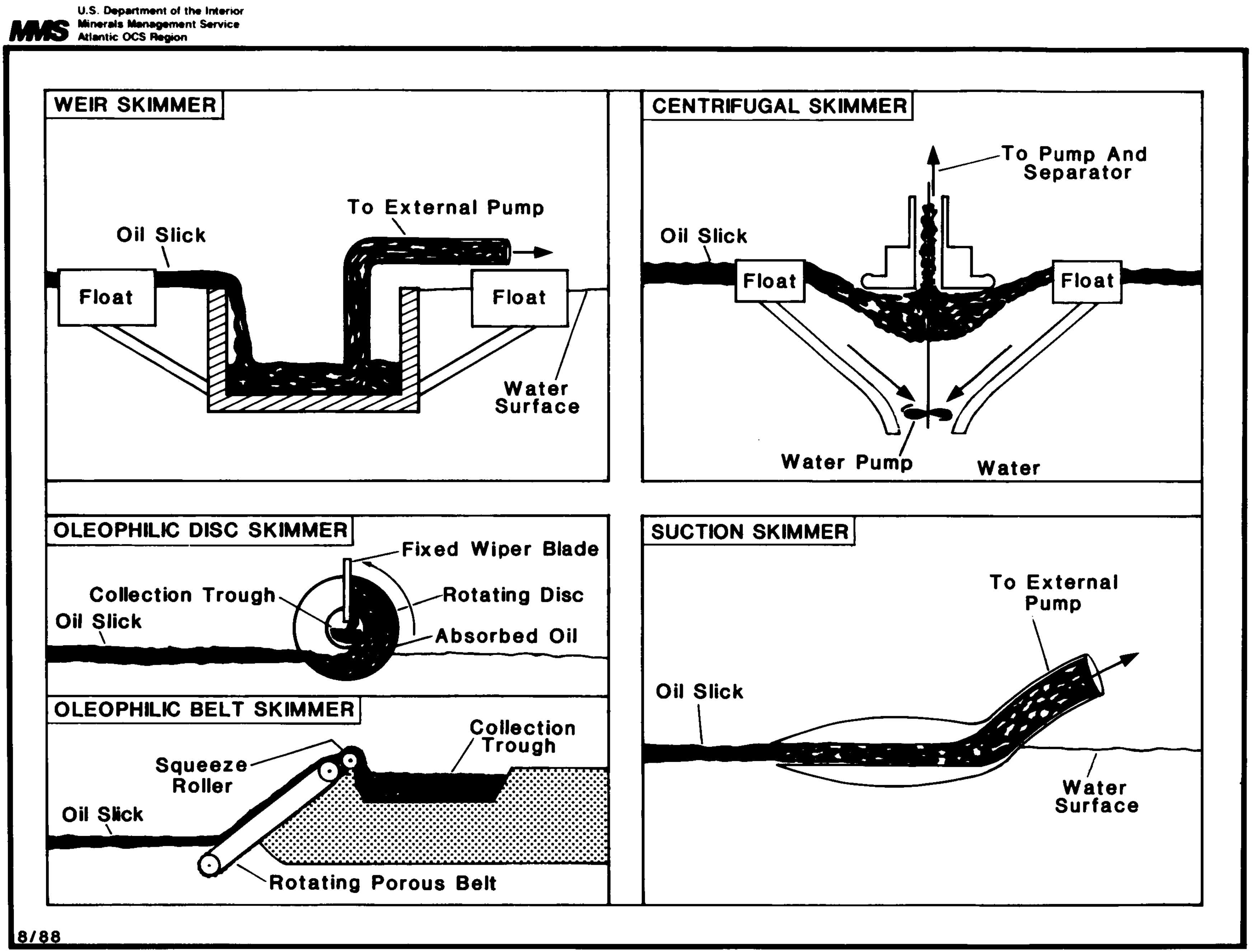
Skimmers are mechanical devices designed to remove oil from the water surface for disposal. They can be used in conjunction with containment booms which are deployed to increase the thickness of the oil slick and to divert oil into the skimmer. Skimmer performance is typically quantified by three parameters:

Recovery Efficiency (RE) - percent oil in the recovered mixture,

Throughput Efficiency (TE) - ratio of oil recovered to oil encountered, and

Oil Recovery Rate (ORR) - rate at which pure oil is being recovered.

Skimmers are broadly classified into four categories according to their basic principle of operation. In addition, some "hybrid" skimmers use a combination of methods to recover oil. The basic principles of operation are illustrated in Figure 3.4.2-1.




Source: Modified from Fingas et al., 1978

Figure 3.4.2-1. Operating principles of skimmers

(1) Weir Skimmers rely on gravity to drain oil off the water surface. Oil on the water surface flows or is pushed over the weir by prevailing currents. Once collected in a sump below the surface, pumping equipment removes the oil to a storage area. Because these skimmers are relatively simple, reliable, and widely available, they are frequently used in small spills. They are very effective in calm water or a gentle swell. However, their efficiency rapidly decreases in waves. In addition, some conventional weirs tend to become clogged with debris or highly viscous oil.

(2) Suction skimmers are adjusted to float at the oil-water interface and use an external vacuum pump to remove oil from the mouth of the skimmer. Because of their compactness and shallow draft, suction skimmers are particularly useful in shallow water and in confined areas. These skimmers have the disadvantage of being easily clogged with debris if no screen is used, and they rapidly loose effectiveness in choppy water. The advantage of this class is that they are capable of efficiently recovering a wide range of different viscosity oils in relatively thick slicks. They are rarely used offshore.

(3) Centrifugal skimmers operate by creating a water vortex, or whirlpool which draws the oil into a collection area. Subsequently, a pump draws off the oil to a separator. Due to the depth of the skimmer inlet, these skimmers can recover emulsions floating beneath the surface in addition to oil on the surface. Turbulent sea conditions diminish the efficiency of these skimmers. Consequently, these skimmers are used rarely offshore.

(4) Oleophilic skimmers use a surface to which oil (but not water) adheres to remove oil from the water surface. The sorbent surfaces (drums, discs, belts, or ropes) are continuously moved through the water. Oil collected by the sorbent surface is removed by a wiper blade or pressure roller and pumped to a collection area. In general, the RE of this type of skimmer is much higher than that of other skimmers. In addition, the oleophilic disc skimmer has the advantage of working effectively in fairly high sea states. Because of these attributes, disc skimmers are highly effective offshore recovery systems.

Skimmer effectiveness depends on a number of factors including oil characteristics, slick thickness, ambient oceanographic conditions, and the skimmer's pumping or sorbtive capacity (Johnson and Pastorok, 1985). Most skimmers operate at maximum efficiently when the slick is relatively thick and the water is calm. Due to the varying principles of operation and recovery capacity, each class of skimmer has distinct advantages and disadvantages. Table 3.4.2-1, which compares skimmers, shows oil recovery rates (ORR) up to 700 $m^3/h$ and operational capability in seas up to 3 m (10 ft) in height. Also, the effect of waves varies widely with each class of skimmer, with the oleophilic disc and centrifugal skimmers being most effective in rough seas.

Development and testing of new or specialized skimmers are continuously undertaken by industry and government. In June 1983, three French skimmers were evaluated in offshore field trials (Peigne, 1985). The skimmers tested were the SIRENE 20 skimming boom, the ESCA offshore weir-type boom, and the STOPOL oleophilic skimmer associated with a deflecting boom. The trials confirmed the ability of the three devices to recover oil effectively in moderate to rough seas (sea state 3 to 4). Trials were conducted using a fuel oil with a viscosity of 800 cSt at 14° C (57° F), the average temperature during the tests. In all, 35 $m^3$ of oil were spilled and 25 $m^3$ were recovered. The three skimmers averaged about 70 to 80 percent TE. Due to variability of the sea state and difficulties in emptying the floating tank, test results for

Table 3.4.2-1. Use and limitations of skimmers

| Skimmers | Type of Oil | Capacity | Weather Conditions: Waves, Wind, and Currents |
|---|---|---|---|
| Weir skimmers self levelling units | Efficient with all kinds of oil and with water-in-oil emulsions provided viscosity is not too high | Max. ORR: 10 $m^3/h$ | Inefficient in waves higher than 0.3 m (1 ft) |
| Oleophilic disc skimmers | All kinds of oil Efficiency is poor in emulsion ($u \geq 3,000$ cSt) | ORR: 10 to 400 $m^3/h$<br>RE: 40 to 90 percent | Claimed to work in seas up to 1 to 3 m (3 to 10 ft) |
| Oleophilic belt skimmers | Non-viscous oil ($u \leq 1,000$ cSt) | ORR: 10 to 300 $m^3/h$<br>RE: 50 to 90 percent | Efficient in calm water, poor efficiency in waves |
| Centrifugal skimmers | All kinds of oil except viscous oil ($u < 1,000$ cSt) and emulsions | ORR: 10 to 700 $m^3/h$<br>RE: 40 to 80 percent | Used with waves up to 1.5 m (5 ft) |
| Suction skimmers | All kinds of oil and emulsions | ORR: 5 to 200 $m^3/h$ | Rarely used at sea |
| Skimming barrier | All kinds of oil except highly viscous emulsions ($u \geq 5,000$ cSt) | ORR: 100 to 2,700 $m^3/day$ | Efficiency decreases drastically in waves greater than 0.5 m (1.6 ft) |

Source: Modified from Johnson and Pastorok (1985), their Table 2.4.

the three skimmers are not directly comparable. However, the relative strengths and disadvantages of each system are apparent. Working in sea states up to 4 (significant wave height to 2.1 m [6.9 ft]), the SIRENE is the least affected by waves. The ESCA is the least affected by variations in viscosity and thickness of oil encountered, while the STOPOL is the most selective. Because the ESCA recovers large amounts of water along with the oil, it is associated with a vessel or barge with a large storage capacity.

In another open ocean operation, a Coast Guard skimming barrier was used by the NSF for containing and collecting oil from the *Ixtoc I* blowout in the Gulf of Mexico, Bay of Campeche. It was reported to exceed operational and survival estimates without significant failure of any physical barrier component (O'Brien, 1981). The system was designed to contain oil in 1.5-m (5-ft) waves, 37-km/hr (20-kt) winds, and 2-km/hr (1-kt) currents and to survive 3-m (10-ft) waves, 74-km/hr (40-kt) winds, and 3.7-km/hr (2-kt) currents. During actual recovery operations, the system contained oil and allowed it to be recovered successfully in 74-km/hr (40-kt) winds and 3.7-m (12-ft) seas. Average conditions during the operation approached 1.5-m (5-ft) swells, 28-km/hr (15-kt) winds, and 2-km/hr (1-kt) currents.

### 3.4.3 Dispersants

Dispersion is the process by which oil is broken into fine droplets that are more easily dispersed into the water column. As discussed in Chapter 2, oil will disperse naturally as it spreads and weathers. Natural dispersion can be accelerated by the application of dispersants. When added to an oil spill, chemical dispersants act to decrease the amount of energy required to convert an oil slick into droplets by reducing the interfacial tension between the oil and water molecules. This reduces the cohesiveness of the oil film, making it easier to break into small droplets. If mechanical containment and recovery are insufficient, an advancing oil slick can be treated with a dispersant. Generally, it is preferable to disperse an oil spill at sea rather than allowing it to approach near-shore environments. Dispersants are most effective when applied to unweathered oil slicks in relatively warm water. The advantages of dispersant application include increased rate of oil degradation, less tendency for the oil to form tarry residues, less contamination of beaches, and decreased impact on waterfowl from oiling. Disadvantages include potential toxic effects of the dispersant to aquatic life and increased exposure of organisms to toxic hydrocarbons in the dispersed oil.

Dispersant effectiveness is primarily limited by the characteristics of the oil, environmental conditions, and the application technique. There is a decrease in dispersant effectiveness as oil viscosity increases, especially above 2,000 cSt. Highly viscous oils and oils with a high wax or asphaltene content resist dispersion (Canevari, 1985). Also, dispersants have limited effectiveness on thin or patchy slicks. Very low viscosity oils spread rapidly into a thin layer only a few molecules thick. This results in poor mixing of the dispersant with the oil layer (Delvigne, 1985).

Environmental conditions such as temperature, water salinity, and oceanographic conditions are key elements in dispersant performance. Temperature has a two-fold impact on dispersant action. Because highly viscous oil does not disperse well, cold water decreases the effectiveness of the dispersant. Temperature also directly alters the activity of dispersant ingredients. Similarly, water salinity can have a significant effect on dispersant performance by altering the ionic environment (Canevari, 1985). Some form of energy (wind and waves or mechanical) must be available to mix the dispersant into the slick and to carry the droplets away.

Proper dispersant application is also an important factor in maximizing dispersion. Dispersants may be applied by surface vessel or by aircraft. The goal is to maximize the amount of dispersant mixing with the oil by carefully adjusting the dose rate. To accomplish this, the correct dose of dispersant must be deposited evenly on the surface of the oil slick. This involves calculation of the relationships among the pump capacity, chemical dilution rate, speed of the craft, and effective swath width covered (Lindblom, 1979). Dispersant droplet size should be adjusted to maximize the amount of chemical reaching the slick and mixing uniformly with the oil. Very small droplets are subject to drift as an aerosol (Lewis, 1985), while very large drops do not mix effectively with oil slicks.

Use of dispersants is regulated under both the NCP and regional plans. Section 311(c)(2)(G) of the Clean Water Act requires that EPA prepare an NCP Product Schedule of dispersants and other chemicals that may be used in implementing the Plan. The OSC, with the concurrence of both the EPA representative to the RRT and the States with jurisdiction over the navigable waters polluted by the spill, may authorize the use of a dispersant from the NCP Product Schedule. The OSC must consider hazards to human life, toxic effects on marine biota, and effectiveness of other methods before approving the application of a dispersant. Concurrent approval, however, is not needed if the use of dispersants is necessary to prevent or substantially reduce the hazard to human life.

The use of dispersants has been a controversial topic since the *Torrey Canyon* incident. Until recently, the toxicity and environmenal effects of dispersants have been the primary issue. Older dispersants contained a large proportion of inherently toxic hydrocarbon-based solvents such as kerosene and mineral spirits. Today, the major organic solvents contained in dispersants are less toxic (alcohols, glycols, and glycol ethers). Concern is now focused on the effectiveness of dispersants at sea, rather than their toxicity. Most recently, Fingas (1988) reviewed the results of field experimental spills conducted over the past 12 years. According to his review of the literature, effectiveness values range from 2 to 100 percent, averaging 33 percent. Fingas believes these values are high because of faulty assumptions used to calculate effectiveness. He concludes that effectiveness of dispersants in the field is questionable because a number of physical/chemical processes intervene in field situations to bring effectiveness values below those measured in the laboratory.

### 3.4.4 Sorbents

Another recovery method for cleaning up spilled oil is the use of sorbents. Sorbents are defined as any material which will recover oil through either absorption or adsorption. Absorbtion occurs when oil penetrates into the interior of the sorbent, while adsorption occurs when one substance is attracted to and adheres to the surface of another. Sorbents are useful for cleanup of small spills, spills in areas inaccessible to skimmers, and removal of oil left by other recovery operations.

There are three broad categories of sorbents (1) natural organic sorbents such as straw, peat moss, sawdust, milled corn cobs, and hay; (2) synthetic organic sorbents such as rubber, polyurethane, polypropylene, polyethylene, and other organic polymers; and (3) mineral-based sorbents such as perlite, vermiculite, glass wool, and volcanic rock.

Some sorbents are treated with oleophilic and hydrophobic agents to improve the oil-wetting ability of the material. This treatment increases the ability of the sorbent to remain afloat once it has sorbed oil. Natural organic sorbents such as peat moss and sawdust soak up water along with oil, sink when saturated with water, and add to the cleanup problem. Another potential problem is that most skimmers are easily clogged by sorbent materials. Thus, use of sorbents early in the cleanup operation may impede the efficient recovery of oil.

Specific advantages and disadvantages of each basic class of sorbent are listed in Table 3.4.4-1. In general, synthetic sorbents have exceptionally high recovery efficiency and are easy to apply and recover. However, they are not biodegradable and are relatively expensive. In contrast, natural sorbents collect only three to six times their weight in oil, but are biodegradable and non-toxic. Finally, natural inorganic sorbents recover up to eight times their weight but are persistent in the environment and are difficult to distribute when windy.

Table 3.4.4-1. Summary of sorbent materials

| Type | Advantages | Disadvantages | Example | Oil Capacity[a] |
|---|---|---|---|---|
| Natural sorbents | Non-toxic materials<br>Will biodegrade | Sorb both oil and water and will sink when saturated<br>Recovery of large amounts of sorbent is a labor-intensive operation<br>Trapped oil may drain off material | Peat moss<br>Straw<br>Milled corn cobs<br>Wood cellulose fiber<br>Milled cottonseed fiber | In general, absorb 3 to 6 times their weight in oil |
| Inorganic or mineral-based sorbents | | Very light materials and are difficult to distribute when windy<br>Nonbiodegradable<br>Dust may cause respiratory irritations<br>Can be abrasive to recovery equipment | Perlite<br>Vermiculite<br>Volcanic ash | In general, absorb 4 to 8 times their weight in oil |
| Synthetic sorbents | Exceptionally high recovery efficiencies<br>Some materials can be reused after oil removal | Expensive<br>Nonbiodegradable | Polyurethane<br>Urea formaldehyde<br>Polyethylene<br>Polypropylene | Variable, but higher than nonsynthetic sorbents (some 12 to 16 times their weight in oil) |

Table 3.4.4-1 Summary of sorbent materials - Continued

| Type | Advantages | Disadvantages | Example | Oil Capacity[a] |
|---|---|---|---|---|
| | Easily spread | | | |
| | Easily recovered | | | |
| | Available in many forms (rolls, sheets, booms) | | | |
| Synthetic foam sorbents | Most efficient sorbents available | Oil-saturated slabs may tear during recovery | Polyurethane foam | Typically highest available |
| | Efficiency independent of oil viscosity | | | |
| | Can produce material at site by mixing two liquids | | | |

[a] More specific capacities may be found in Byroade et al. (1981), and Robertson (1983).
Source: Modified from Byroade et al. (1981) and Johnson and Pastorok (1985).

# Glossary of Abbreviations

## GLOSSARY OF ABBREVIATIONS

| | |
|---|---|
| API | American Petroleum Institute |
| BAT | Best Available Technology Economically Achievable |
| BCT | Best Conventional Pollutant Control Technology |
| BOD | Biological Oxygen Demand |
| BPT | Best Practicable Control Technology Currently Available |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| CFR | Code of Federal Regulations |
| CWA | Clean Water Act |
| DO | Dissolved Oxygen |
| DOC | U.S. Department of Commerce |
| DOI | U.S. Department of the Interior |
| EG&G | Edgerton, Germeshausen, and Grier - Environmental Consultants |
| ENDECO | Environmental Devices Corporation |
| EPA | Environmental Protection Agency |
| FIFRA | Federal Insecticide, Fungicide and Rodenticide Act |
| FWPCA | Federal Water Pollution Control Act |
| LANTAREA | Atlantic Area Strike Force |
| MMS | Minerals Management Service |
| MOU | Memorandum of Understanding |
| NAS | National Academy of Sciences |
| NCP | National Oil and Hazardous Substances Pollution Contingency Plan |
| NOAA | National Oceanic and Atmospheric Administration |
| NPDES | National Pollutant Discharge Elimination System |
| NRC | National Research Council |
| NSPS | New Source Performance Standards |
| NRT | National Response Team |
| NSF | National Strike Force |
| OCS | Outer Continental Shelf |
| OCSLA | Outer Continental Shelf Lands Act |
| ORR | Oil Recovery Rate |
| OSC | On-Scene Coordinator |
| OSCP | Oil Spill Contingency Plan |
| RE | Recovery Efficiency |

| | |
|---|---|
| RRC | Regional Response Center |
| RRT | Regional Response Team |
| TE | Throughput Efficiency |
| U.S.C. | United States Code |
| USGS | U.S. Geological Survey |

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DOC See U.S. Department of Commerce.

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# APPENDIX

## Memorandum of Understanding Between the USGS and the U.S. Coast Guard

## MEMORANDUM OF UNDERSTANDING BETWEEN THE USGS AND THE U.S. COAST GUARD

MEMORANDUM OF UNDERSTANDING BETWEEN THE
UNITED STATES GEOLOGICAL SURVEY
OF THE DEPARTMENT OF THE INTERIOR
AND THE
UNITED STATES COAST GUARD
OF THE
DEPARTMENT OF TRANSPORTATION
CONCERNING REGULATION OF ACTIVITIES
AND FACILITIES ON
THE OUTER CONTINENTAL SHELF OF THE UNITED STATES

I. Purpose:

The purpose of this Memorandum of Understanding is to promote the safety of activities and facilities on the Outer Continental Shelf of the United States (OCS) associated with the exploration, development, and production of mineral resources, to avoid duplication of effort, and to promote consistent, coordinated and less burdensome regulation of these facilities.

II. Definitions:

For purposes of this Memorandum of Understanding, the following definitions apply:

Act - The Outer Continental Shelf Lands Act of 1953 (43 U.S.C. 1331 et seq.), as amended by the Outer Continental Shelf Lands Act Amendments of 1978 (Pub. L. 95-372).

Deepwater Port - A facility licensed by the Secretary of Transportation under the Deepwater Port Act of 1974.

Vessel - Every description of watercraft or other artificial contrivance used, or capable of being used, as a means of transportation on the water. This term does not include atmospheric or pressure vessels used for the containment of fluids or gases.

Outer Continental Shelf - The submerged lands which are subject to the Act.

OCS Activity - Any offshore activity associated with exploration for, development of, or production of mineral resources of the OCS.

OCS Facility - Any artificial island, platform, installation, or other device, permanently or temporarily attached to the seabed or subsoil of the OCS, and used for any OCS activity. This term does not include a deepwater port or vessel engaged in transportation, but does include a:

1. Fixed OCS Facility - Any fixed, bottom-founded facility permanently attached to the seabed or subsoil of the OCS, including platforms, guyed towers, articulated columns, gravity platforms and other structures;

2. Floating OCS Facility - Any buoyant facility securely and substantially moored to the seabed or subsoil of the OCS, including tension leg platforms, permanently moored semi-submersibles, ship/barge shape hulls, or other buoyant structures. This term does not include mobile offshore drilling units;
3. Mobile Offshore Drilling Unit (MODU) - Any vessel capable of engaging in drilling operations for the exploration or exploitation of mineral resources of the OCS. This term includes mobile offshore drilling units engaged in OCS activities that are U.S., foreign, or not documented under the laws of any nation;
4. OCS Terminal - Any fixed or floating facility which is used or intended for use primarily as a port or terminal for transferring produced oil, gas or other OCS mineral resources to or from a vessel;
5. Mobile Well Servicing Unit (MWSU) - Any vessel other than a MODU which engages in well servicing operations on the OCS.

III. Agency Authorities on the OCS:

A. General:

1. The Department of the Interior is responsible for management of mineral leasing on the OCS of the United States, including coordinating Federal activities related to this program. Within the Department of the Interior, the U.S. Geological Survey regulates all mineral exploration, drilling, and production activities on leased or leasable land.
2. The United States Coast Guard of the Department of Transportation regulates to promote the safety of life and property on OCS facilities and vessels engaged in OCS activities, and the safety of navigation.

B. Statutory authorities of the Geological Survey on the OCS include:

1. Providing for the prevention of waste and the conservation of the natural resources of the OCS, and the protection of correlative rights.
2. Requiring suspension or temporary prohibition of any operation or activity on a lease if there is a threat of serious or irreparable harm or damage to life, to property, to mineral deposits or to the marine, coastal, or human environment.
3. Reviewing allegations of violations of safety regulations issued under the Act.
4. Reviewing and approving exploration plans, development and production plans, and applications for permits to drill necessary for prompt and efficient exploration, development, and production of a lease area.
5. Reviewing and approving applications for remedial work on completed wells.
6. Approving rights of use and easement.
7. Inspecting drilling and production operations to ensure compliance with applicable lease terms and Geological Survey regulations and orders.
8. Ensuring compliance with the national ambient air quality standards pursuant to the Clean Air Act (42 USC 7401 et seq.), to the extent that activities authorized under the Act significantly affect the air quality of any State.
9. Exercising the Secretary of the Interior's responsibilities for the assessment, compromise, and collection of civil penalties under section 24(b) of the Act.

C. Statutory authorities of the Coast Guard on the OCS include:

1. Promoting the safety of life and property on OCS facilities and adjacent waters.
2. Requiring hazardous working conditions related to activities on the OCS to be minimized.
3. Reviewing allegations of violations of occupational safety and health regulations under the Act.
4. Administering applicable vessel navigation, safety and inspection laws contained in Titles 46 and 33 of the United States Code.
5. Inspecting OCS facilities and vessels engaged in OCS activities to ensure compliance with applicable Coast Guard requirements.

D. Similar statutory authorities involving both agencies include:

1. Establishing minimum requirements or standards of design, construction, alteration, and repair for vessels, rigs, platforms, or other vehicles or structures engaged in OCS activities.
2. Performing scheduled and unannounced inspections of OCS facilities to assure compliance with regulations promulgated pursuant to the Act.
3. Enforcing regulations promulgated pursuant to the Act, including authority to utilize by agreement the services of personnel or facilities of other Federal agencies.
4. Investigating and making public reports on deaths, serious injuries, fires, and oil spillage occurring as a result of OCS Operations.
5. Requiring the use of the best available and safest technologies on OCS drilling and production operations as set forth in section 21(b) of the Act.

IV. Responsibilities:

To accomplish the purposes of this memorandum both agencies agree to observe the following guidelines with respect to overseeing OCS facility design and construction, systems and equipment, and operations.

A. Facility design and construction requirements, including plan approval:

1. The Geological Survey exercises technical review and approval responsibility for design, fabrication, and installation of all fixed OCS facilities. Additionally, after technical review and approval of the design and fabrication of all floating OCS facilities by the Coast Guard, the Geological Survey will have final approval responsibility for the installation of such facilities. The Geological Survey will coordinate technical and plan review as necessary with the Coast Guard to ensure that any applicable Coast Guard requirements affecting design or construction are complied with.

The Geological Survey verifies the following for all OCS facilities:

a. Site-specific considerations, such as oceanographic, meteorological, geological and geophysical conditions including bottom conditions and the capability of the seabed to support or hold the position of the facility to be installed and operated.

The Geological Survey established requirements and verifies the following for fixed OCS facilities:

b. Structural integrity involving design, fabrication, and installation;
c. General arrangement of drilling, production, and well control systems and equipment;
d. Modification and repair related to structural integrity.

2. The Coast Guard exercises technical review and approval responsibility for design and construction of all floating OCS facilities, and all vessels engaged in OCS activities, including MODUs and MWSUs. The Coast Guard will coordinate technical and plan review as necessary with the Geological Survey to ensure that any applicable Geological Survey requirements affecting design or construction are complied with.

The Coast Guard establishes requirements for the following on all OCS facilities:

a. Structural fire protection, including specifying fire endurance capabilities of bulkheads, decks, escape routes, testing and classification of materials, and requirements for ventilation systems;
b. Access, landings and emergency escape routes.

The Coast Guard establishes requirements for the following on floating OCS facilities and vessels engaged in OCS activities:

c. Design, loading, fabrication and construction requirements;
d. Stability and buoyancy;
e. Modification and repair requirements related to structural integrity;
f. General arrangement.

B. <u>Systems and Equipment</u>:

Systems approved by one agency which are interconnected to systems approved by the other agency must be acceptable to both agencies.

1. The Geological Survey establishes requirements and verifies compliance with those requirements for systems and equipment for drilling, production, well control, and workover, on all OCS facilities.

Systems and equipment for which the Geological Survey establishes requirements, as necessary, on all OCS facilities include:

a. Blowout preventer and other well control equipment;
b. Surface production safety systems;
c. Emergency Shutdown System (ESD), including associated gas and fire detection systems;
d. Subsurface well-control equipment, including safety valves;
e. Atmospheric, pressure and fired vessels used for the processing of production;
f. Wellhead and flow-line equipment, including valves and sensors for wellheads, flow lines, and pipelines;
g. Dehydration equipment and gas compressor units used in production operations;

h. Hydrogen sulfide control equipment, including the hydrogen sulfide gas detection system;
i. Production and production-associated piping systems, including incoming and departing pipelines;
j. Pumps used to transfer liquids within the production process systems and into pipelines;
k. Fire Loop System which is used for detection and to initiate platform shutdown;
l. Subsea completions;
m. Wellhead fire-prevention;
n. Gas detection systems for drilling, production or gas transmission systems or equipment;
o. Oil and gas sale and metering equipment for production from OCS leases;
p. Containment systems for overflow from equipment associated with drilling and production.

Other systems and equipment for which the Geological Survey is responsible on fixed facilities include:

q. Electrical system design and equipment, including designation of classified locations;
r. Pressure vessels and piping associated with drilling operations;
s. Engine exhaust insulation and spark arrestors.

2. The Coast Guard establishes systems and equipment requirements, as appropriate, for propulsion machinery, auxiliary machinery and personnel safety equipment on all OCS facilities. The Coast Guard also establishes requirements for equipment on all OCS Facilities to mitigate occupational safety or health hazards, or ensure the seaworthiness of a MODU, MWSU, floating OCS facility, or vessel. However, the Coast Guard will not establish requirements for drilling, production or workover equipment that would duplicate or conflict with Geological Survey requirements. Nor will the Coast Guard establish requirements for safety factors, shutdown or relief valves for pressure vessels or piping in systems for which Geological Survey has design approval.

Systems and equipment for which the Coast Guard establishes requirements, as necessary, on all OCS facilities include:

a. Lifesaving systems and equipment;
b. Fire detection, control and extinguishing systems and equipment not covered under IV.B.1.(c) and (k) of this Memorandum;
c. General alarms;
d. Cranes, booms or other material handling equipment, including industrial trucks;
e. Personnel protection equipment, excluding equipment for protection from hydrogen sulfide;
f. Communications;
g. Helicopter fueling facilities;
h. Helicopter deck installations;
i. Navigation lights, obstruction lights, and sound signals;
j. Boilers, pressure vessels, and piping not covered under IV B. 1. of this Memorandum;

k. Underwater working chambers designed for human occupancy and their support systems;
l. Hotel services including fresh water, flushing water, heating systems, etc.;
m. Permanent and portable quarters.

Other systems and equipment for which the Coast Guard establishes requirements, as necessary, on floating OCS facilities, MODUs, MWSUs, and vessels include:

n. Electrical system design and equipment, including designation of classified areas;
o. Mooring systems.

Other systems and equipment for which the Coast Guard establishes requirements, as necessary, on OCS terminals include:

p. Oil transfer, gas inerting and vapor recovery systems.

C. <u>Operations</u>:

1. The Geological Survey administers procedures, including training, drills, inspections and emergency procedures on all OCS facilities with respect to:

   a. Drilling, workover, and protection operations, including well control;
   b. Pollution prevention, except for transfers to or from a vessel (as vessel is defined in section II. of this Memorandum);
   c. Safe welding, burning and hot tapping procedures;
   d. Control of hydrogen sulfide;
   e. Pipeline operations associated with an OCS facility;
   f. Well-head and platform removal.

Other procedures which the Geological Survey administers on OCS fixed facilities include:

   g. Underwater and above water structural inspection and repair.

2. The Coast Guard administers requirements, including those for training, drills, inspections and emergency procedures, on all OCS facilities for:

   a. Firefighting;
   b. Emergency egress from a facility, including use of lifesaving and other general emergency equipment;
   c. Handling, transfer and stowage of explosives, radioactive flammable (other than produced hydrocarbons), and other hazardous materials;
   d. Transfer of petroleum and other products from or to a vessel (as vessel is defined in section II. of this Memorandum);
   e. Transfer of materials and personnel on or off the facility by crane or other means;
   f. Vehicles and vessel operations;
   g. Helicopter operations on OCS facilities;
   h. Occupational safety and health of personnel;
   i. Diving operations.

Other requirements which the Coast Guard administers on OCS floating facilities and vessels include:

j. Underwater and above water structural inspection and repair;
k. Stability considerations.

V. Inspections:

A. Each agency will conduct scheduled and unannounced inspections, as necessary, to ensure compliance with its own requirements. Both agencies will coordinate inspections to minimize disruption of operations. If in the course of a routine inspection, deficiencies falling within the responsibility of the other agency are apparent, the deficiencies will be reported to the other agency for action. This is nothing intended, however, to prevent any inspector from either agency from taking such action as is considered necessary to prevent serious or irreparable harm to persons, property or the environment on the OCS. Such action, however, will be subsequently reported to the other agency.
B. The Geological Survey administers procedures for requiring shut-down of drilling and production operations and may initiate such procedures upon request by the Coast Guard.
C. The Coast Guard issues certificates indicating compliance with Coast Guard requirements for all floating OCS facilities and vessels engaged in OCS activities, including MODUs and MWSUs.

VI. Investigations:

A. Responsibility:

Investigation and public report by the Geological Survey or the Coast Guard are required for fires, oil pollution, deaths and injuries associated with OCS activities. In addition, the agencies investigate certain other incidents relating to other regulatory responsibilities, e.g. loss of well control, sinking, capsizing, or major damage to a vessel or facility. To avoid duplicative efforts and simplify administration, the primary agency regulating a particular facility, system, or operation will be responsible for leading the investigation and reporting on incidents involving that facility, system, or operation. Where only one agency has an investigative interest in an incident, that agency will investigate and report. Where both agencies have investigative interest in an incident, one agency will assume lead responsibility with supporting participation by the other agency. Assumption of lead agency responsibility, the extent of supporting participation, and procedures for coordination will be determined by the circumstances of the particular incident. Normally, all investigations which involve both agencies will be coordinated by applying the following guidelines in numerical order to determine lead agency.

B. Guidelines:

1. Collisions - The Coast Guard will normally be the lead agency.
2. Fires and Explosions - The Geological Survey will normally be the lead agency for incidents of fires or explosion involving drilling or production operations. Coast Guard participation will be requested in all investigations of fires or explosions that involve death or injuries or vessels,

equipment, or operations for which the Coast Guard is responsible under paragraphs IV.B.2. or C.2. of the Memorandum.

3. Deaths and Injuries - The Coast Guard will normally be the lead agency for all incidents involving death or injuries. Geological Survey participation will be requested in investigations of all deaths and injuries associated with oil or gas drilling or production operations or equipment, including hydrogen sulfide exposure.
4. Pollution - The Geological Survey will normally be the lead agency for incidents involving pollution from all OCS facilities. Coast Guard participation will be requested in all investigations of pollution.
5. Facilities, Material and Equipment.

   a. The Coast Guard will normally be the lead agency for incidents involving damage to MODUs, MWSUs, or other vessels, or floating OCS facilities, and failure of or damage to propulsion, auxiliary, or emergency systems and equipment covered under IV.B.2. of this Memorandum.
   b. The Geological Survey will normally be the lead agency for all other incidents involving failure of or damage to fixed OCS facilities.

C. Conduct of Investigations:

1. The lead agency responsible for an investigation under these guidelines will conduct, review, approve and release the investigation report in accordance with the normal procedures of that agency. Comments by the supporting agency will be included in the investigation report.
2. If both agencies participate in an investigation, the lead agency will forward an information copy of the final report to the supporting agency.
3. Reports prepared by a single agency need not be routinely forwarded to the other agency, but will be available upon request.

VII. Oil Spill Contingency Plans:

Exploration Plans or Development and Production Plans are submitted to the Geological Survey for review and approval. The Coast Guard will provide a technical review of that portion of the Plan which addresses the adequacy of the oil spill contingency plan, including the adequacy of oil spill response, clean up equipment, and procedures. The criteria by which to judge the adequacy of a plan will be jointly agreed upon by the Geological Survey and the Coast Guard.

VIII. Exchange of Services and Personnel:

To the extent its own operations permit, each agency will provide the other agency with such assistance, technical advice and support, including transportation, as may be requested. Such exchange of services and use of personnel shall be on a non-reimbursable basis.

IX. Cooperation in Standards and Regulation Development:

A. Both agencies will exchange data and study results, participate in research and development projects of mutual interest, and exchange early drafts of rulemaking notices.

B. Both agencies will review current standards, regulations and orders and will propose revisions to them as necessary in keeping with the provisions of this Memorandum of Understanding.
C. Both agencies will review reporting and data collection requirements imposed on operators of OCS facilities and, wherever feasible, will eliminate or minimize duplicate reporting and data collection.

X. Implementation:

A. Each agency will review its internal procedures and where appropriate, will revise them to accommodate the provisions of this Memorandum of Understanding. Each agency will also designate one senior official who will be responsible for continuing coordination and implementation of the provisions of this Memorandum of Understanding.
B. On the effective date of this agreement, the Coast Guard/Geological Survey Memorandum of Understanding for mobile offshore drilling units, dated April 11, 1977, is canceled.

XI. Savings Provision:

Nothing in this Memorandum of Understanding shall be deemed to alter, amend, or affect in any way the statutory authority of the Geological Survey or the Coast Guard.

XII. Effective Date:

This Memorandum of Understanding is effective upon signature. It may be amended at any time by mutual written agreement of both agencies and may be terminated by either agency upon 30 days written notice.

Signed at Washington, DC the 18th day of December 1980.

*Original signed by*
*J.B. Hayes*

J.B. Hayes
Commandant, U.S. Coast Guard
Department of Transportation

*Original signed by*
*H. William Menard*

H. William Menard
Director, U.S. Geological Survey
Department of the Interior

[Original document on file at the Atlantic OCS Region]